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ORIGINAL ARTICLES.

I.—Notes on new or imperfectly known Chalk Polyzoa.

By R. M. Brydone, F.G.S.

(*Continued from Dec. V, Vol. X, p. 438.*)

(PLATE IV.)

Cribrilina cicatricifera, sp. nov. (Pl. IV, Figs. 1, 2.)

Zoarium unilaminate, adherent.

Zoœcia convex, quite separate, very small, average length ·35 to ·38 mm. and width ·2 mm.; numerous radiating imperforate lines are faintly perceptible on some of them in a suitable light, and were doubtless present on all; they are hardly 'furrows', resembling rather superficial cuts; apertures very slightly heel-shaped.

Oœcia abundant, relatively large, globose with a strongly concave free edge.

Avicularia perhaps represented by the tiny bodies like abortive zoœcia, with long, narrow apertures which are scattered freely over the zoarium.

This dwarf form occurs sparingly in the zone of *M. cor-anguinum*, and probably persists in small zoaria up to the Weybourne Chalk.

Cribrilina vulnerata, sp. nov. (Pl. IV, Figs. 3, 4.)

Zoarium unilaminate, adherent.

Zoœcia convex, quite separate, small, average length ·4 to ·42 mm. and width ·3 mm., with a few radiating imperforate lines, resembling (but rather more marked than) those of *C. cicatricifera*, visible on many; apertures markedly horseshoe-shaped, rather variable in size; low down at the upper end a well-marked pore often occurs.

Oœcia very large and globose, with a deeply concave free edge, enveloping the upper part of the aperture; they are very abundant, but very fragile, the specimen shown in Fig. 3 being almost the only one I have seen; the broken edges present an appearance quite distinctive under a pocket magnifier.

Avicularia unknown.

This species is abundant in the Trimingham Chalk and occurs sparingly in the Weybourne Chalk. Comparison with the type of *Cellepora megastoma*, Desm. & Lesueur,[1] might show a relation with that species, the figure of which is quite inadequate.

This and the foregoing species clearly illustrate the last stage before the final consolidation of a Cribrilinid front wall.

[1] Bull. Sci. Philomathiques, 1814, p. 54, pl. ii, fig. 5.

MOLLIA LAMINARIA, sp. nov. (Pl. IV, Figs. 5–7.)

Zoarium unilaminate, adherent, consisting of a thin uneven crust out of which the zoœcia rise more or less disconnectedly.

Zoœcia convex, quite smooth, very small, average length ·3 to ·32 mm., generally in contact with others on one or more sides, but sometimes wholly isolated; they show a distinct tendency to linear arrangement; apertures keyhole-shaped and rather short for that type.

Oœcia very large but inconspicuous, globose with a very short concave free edge which slightly impinges on the zoœcial aperture.

Avicularia perhaps represented by the tiny aborted zoœcia which are scattered freely about the zoarium.

Very abundant at Trimingham and not uncommon in the Weybourne Chalk. I place it temporarily in the genus *Mollia* on account of its apparent relationship to *M. guttata*, d'Orb.[1]

It might be a specimen of this form which was figured as *Flustra utricularis* by Samuel Woodward.[2]

HOMALOSTEGA MARGINULA, sp. nov. (Pl. IV, Figs. 8, 9.)

Zoarium unilaminate, adherent.

Zoœcia of moderate size, average length ·5 mm., with circular side walls bent strongly inwards, which at the foot form a distinct thin rim raised slightly above the smooth, flatly arched front wall, but gradually blend into it towards the head; apertures small and superficially semicircular, but apparently contracting progressively downwards into a narrow crescent; fairly large pores occur somewhat irregularly in the side walls when exposed to view.

Oœcia and *avicularia* unknown.

This species occurs very sparingly in the zone of *M. cor-testudinarium* at Seaford and Dover. It seems to have near relations in the early French Chalk, such as *Reptescharellina oceani*, D'Orb.[3]

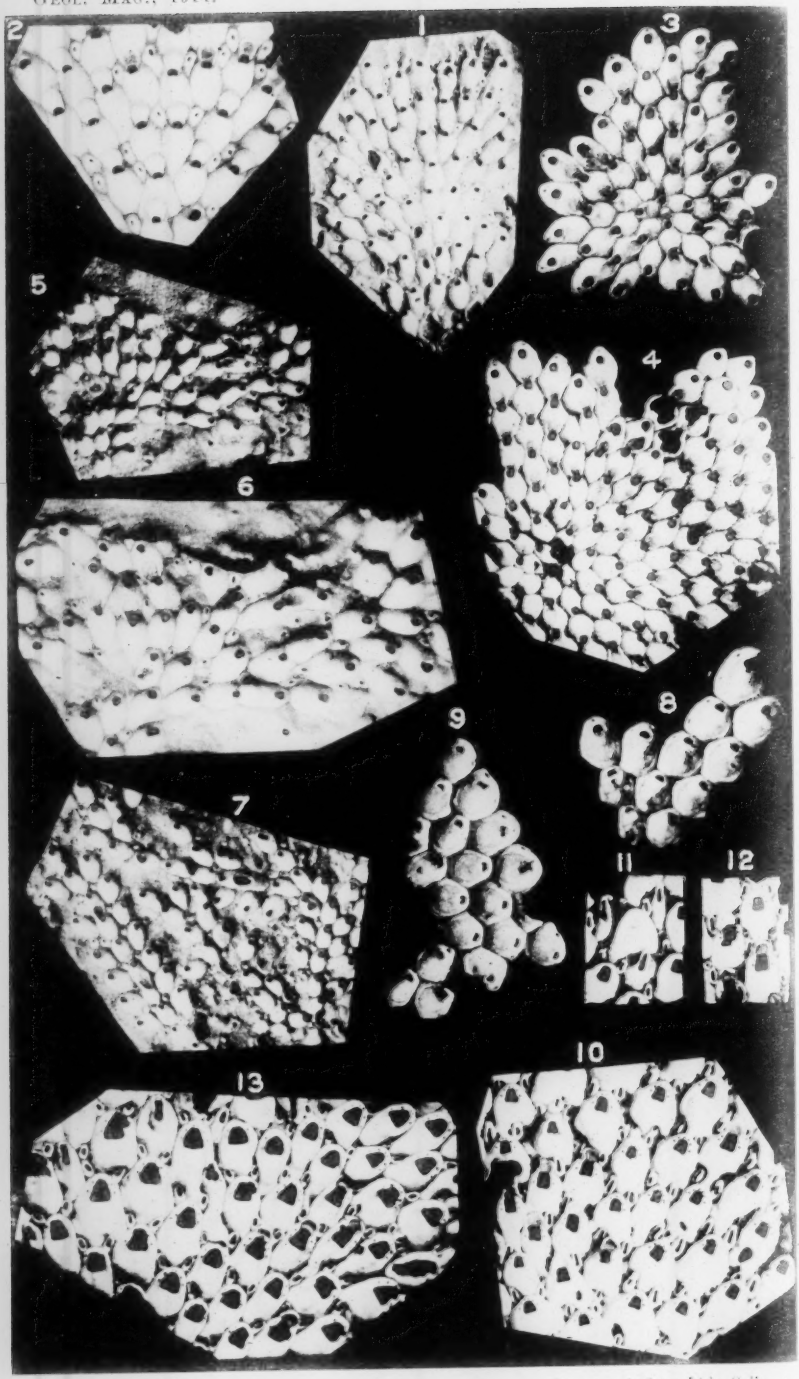
Fig. 8 is given on account of the faint appearance of radiating furrows (? Cribrilinid ancestry) presented by some of the zoœcia.

HOMALOSTEGA NITESCENS, sp. nov. (Pl. IV, Figs. 10–12.)

Zoarium unilaminate, adherent, noticeably bright.

Zoœcia of medium size, average length ·6 to ·65 mm.; front walls flatly arched, slightly below rather sharply defined side walls just below the aperture but rising flush with and merging into them towards the foot; in the upper part of the zoœcium the side walls have a strong tendency to bulge out low down, occasionally producing a sort of external front wall with quite an abrupt margin; apertures small, high, and narrow with a straight lower lip, upwards from which the almost straight sides converge very gradually until they are ended by a very flat arch; paired, circular, flat, wide, perforated spine bases occur on the margin at about half the height, and impinge slightly on the aperture; above them come a pair of pores situate close to the margin just below the upper corners, and another pair occur close together in the centre of the arch.

[1] Pal. Franç. Terr. Crét., tom. v, p. 389, pl. 712, figs. 1, 2.
[2] Geol. Norfolk, by Samuel Woodward, 1833, tab. iv, fig. 7.
[3] Loc. cit., p. 454, pl. 605, figs. 14, 15.



E. M. Brydone, phot. Bemrose & Sons Ltd., Collo...

Chalk Polyzoa.

Oœcia fairly abundant but very delicate, the one figured being the only perfect one I have met with, small, and of the water-bottle type, with a globose body, a strongly constricted neck, and a slightly expanded lip; beneath them the margin of the aperture is deeply cut away.

Avicularia small, mandibular, apertures tending to be hourglass-shaped, very numerous, every zoœcium having normally on either side of its head a slightly diverging pair, whose upper ends rest in hollows in the succeeding zoœcium; others are scattered about irregularly, and some of these develop long convex bodies and may become sub-vicarious.

This species, while distinguishable from *Homalostega vespertilio*, Hag., sp.,[1] by the presence of oœcia and the almost rectangular lower corners of the aperture, would be very near it but for the absence in *H. vespertilio* of the apertural spine bases and pores of *H. nitescens*. On making a special examination of some Trimingham specimens of *H. vespertilio* I found to my great interest that practically every zoœcium had faint traces of a similar arrangement of spines or pores. *H. vespertilio* being confined to the Trimingham Chalk and *H. nitescens* to the Weybourne Chalk, it may fairly be supposed that the former is a direct descendant of the latter, but in this respect has not quite completed its differentiation.

HOMALOSTEGA ANTECEDENS, sp. nov. (Pl. IV, Fig. 13.)

This species is so closely allied to *H. nitescens* that it is adequately described by saying that it is slightly larger, more robust, and less angular; its aperture is very much larger in proportion, its small avicularia smaller and its large avicularia larger and even fully vicarious; and its side walls do not tend to bulge out.

It occurs rarely in the (restricted) zone of *A. quadratus*, Hants and Sussex, and I have one specimen from the zone of *O. pilula* (subzone of abundant *O. pilula*) of Sussex.

EXPLANATION OF PLATE IV.

(All figures × 12 diams. unless otherwise stated.)

FIG. 1. *Cribrilina cicatricifera*. Zone of *M. cor-anguinum*. Gravesend.
,, 2. ,, ,, Part of the same specimen. × 21 diams.
,, 3. ,, *vulnerata*. Trimingham. With oœcium.
,, 4. ,, ,, ,,
,, 5. *Mollia laminaria*. Trimingham.
,, 6. ,, ,, Part of same specimen. × 21 diams.
,, 7. ,, ,, Trimingham. Another specimen.
,, 8. *Homalostega marginula*. Zone of *M. cor-testudinarium*. Dover.
,, 9. ,, ,, ,, ,, Seaford.
,, 10. ,, *nitescens*. Weybourne.
,, 11. ,, ,, ,, Another specimen, showing an operculum preserved.
,, 12. ,, ,, ,, Another specimen with oœcium.
,, 13. ,, *antecedens*. Zone of *A. quadratus*. Shawford, Hants.

[1] Marsson, Die Bryo. d. Weiss. Schreibkreide der Inseln Rugen, p. 94, taf. ix, fig. 15.

II.—On Remains of a Gigantic Land Tortoise (*Testudo gymnesicus*, n.sp.) from the Pleistocene of Menorca.

By Dorothea M. A. Bate.

THE receipt of a grant from the Trustees of the Percy Sladen Fund in 1911 made a return to the Balearic Islands possible in the latter part of the same year. Majorca was visited for the third time while a search for Pleistocene ossiferous remains was undertaken for the first time in Menorca and Ibiza, from which no Pleistocene mammalian remains had previously been recorded. No success attended the search in Ibiza. The deposits discovered in Menorca yielded remains of *Myotragus balearicus*, those of a gigantic land tortoise, and of a large *Eliomys*, which proves to be a hitherto undescribed species.

The remains of *Testudo* were obtained from two rock fissures in the Miocene Limestone of the Bajoli Promontory north of Ciudadela, the former capital of Menorca. In one of these it was interesting to find bones of *Myotragus* associated with those of the Chelonian, although the former only occurred at the highest point of the deposit, of which the greater part had been worn and weathered away. This was the only instance in which these two species were found in the same deposit, although several other localities in the island yielded remains of *Myotragus*.

Although small and of a fragmentary character, the collection which forms the subject of this paper includes specimens representing individuals varying greatly in size and indicating a range between the proportions of *T. pardalis* from South Africa to those equalling, if not surpassing, the dimensions attained by the Madagascan *T. grandidieri*.

Remains of gigantic land tortoises have been found very widely distributed both in the Old World and the New, and existed during many geological epochs in much the same form as their representatives of to-day. Discoveries of Pleistocene forms in the Old World have not, however, been very numerous. Deposits in Madagascar have yielded quantities of remains; but in Europe, Malta and Gibraltar seem to have been, until now, the only localities from which examples had been obtained. Those from Gibraltar consist of only two fragmentary specimens, described by Dr. Leith Adams,[1] who also published a description,[2] with figures, of the small collection of *T. robusta* obtained from the cave deposits of Malta by Admiral Spratt.

During the last few years further Chelonian remains have been obtained by Mr. N. Tagliaferro from various rock fissures in Malta. These are now in the Malta University Museum of Natural History, but casts of nine specimens of limb-bones from Corradino have been presented to the British Museum (Natural History). All these are of large size; one especially, an imperfect humerus, indicates an animal of enormous proportions, equalling, or even surpassing, those of *T. elephantina* from Aldabra. In this (B.M. $\frac{R}{3966}$) the circumference

[1] Quart. Journ. Geol. Soc., vol. xxxiii, p. 188, 1877.
[2] Op. cit., p. 177 et seq., pls. v, vi.

of the narrowest part of the shaft is 184 mm., whilst this measurement for the largest Aldabran specimen given by Dr. Günther is 160 mm.[1]

Mr. Tagliaferro is of opinion that his examples indicate the presence of another race, for which he suggested the name of *T. robustissima* in a letter to the *Daily Malta Chronicle* for February 17, 1913. This makes the third species of large land tortoise to be differentiated and described from Malta.

In Chelonians actual size alone is not a very important characteristic. Like those from Malta, the Menorcan specimens show an enormous range in size; one reason to account for this may be the former very great abundance of reptiles in the island. This suggestion is further borne out by the originally large area of the deposits in which the remains were found. The extreme variability, both in actual size and relative measurements, that obtains in the remains of the gigantic tortoises from Mauritius and Rodriguez has already been pointed out by Professor A. C. Haddon.[2]

Owing no doubt to the great reduction made in the numbers of the existing races of gigantic tortoises since their discovery in the Galapagos Group and islands of the Indian Ocean, chiefly on account of the custom of passing vessels taking great quantities on board, it seems to have become a widely accepted axiom that these creatures are too defenceless to exist except in isolated areas where they would not be subject to the attack of other large animals. It seems that this may hold good in the case of civilized and perhaps semi-civilized man, but not with regard to large carnivora, as for instance Mr. Hay writes:[3] "The large Testudinidæ of North America, from the Lower Eocene to the Pliocene, were exposed to the attacks of large carnivora." He continues to say: ". . . Dr. Leidy has figured the claw phalanx[4] of a species of *Testudo* found in Pleistocene deposits in Hardin County, Texas. The individual must have been one of great size. We do not know why some of the Pliocene gigantic tortoises should not have had descendants in the Quaternary worthy of accompanying the great mammals of that period." Further, it may be remembered that although the only remains of large carnivora obtained from the Malta caves was a single indeterminable tooth, Dr. Falconer,[5] in writing to Admiral Spratt, mentioned that "There are numerous bones in your Zebbug cave collection that are *fiercely* gnawed, and evidently by a large predaceous carnivore".

It seems probable that the extinction of a race of giant tortoises would be more easily brought about by the continued and wholesale destruction of the eggs and young, as, for instance, it has been recorded by Mr. Beck[6] that "On Albemarle the dogs and cats undoubtedly eat a great many young tortoises".

The freedom of the adults from attack has also been brought forward as the cause of the thinning of the shell in some of the races

[1] *Gigantic Land Tortoises in the Collection of the British Museum*, London, p. 31, 1877.

[2] Trans. Linn. Soc., ser. II, Zoology, vol. ii, p. 157, 1881.

[3] *The Fossil Turtles of North America*, Washington, p. 373, 1908.

[4] *Contrib. to the Extinct Vert. Fauna W. Territories*, 1873, pl. xxxiii, fig. 21.

[5] Pal. Mem. London, vol. ii, p. 301, 1868.

[6] *Novitates Zoologicæ*, vol. ix, p. 379, 1902.

of the Galapagos Islands, notably in *T. abingdonii*, which "has a carapace almost as thin as paper in most parts".[1] On the other hand, other isolated forms have thick shells, so it seems that some other explanation is required to account for the variation in this respect. Dr. Günther[2] may have been near the truth when he remarked that this character probably was influenced by the nature of their food and was correlated with their mode of progression. The very great and consistent difference in the size of horns carried by a single species, especially among the deer, in different parts of its habitat is well known, and may perhaps be analogous to the varying thickness of shell in the giant tortoises.

It seems necessary to suppose that there have been considerable changes of climate and vegetation since these giant tortoises roamed the island. That Menorca already was an island is indicated by the discovery of remains of a large race of lerot, probably an insular form. At the present day a small species of land tortoise, *T. græca*, is found in Menorca.

It will be seen from the following description of the Menorcan giant tortoise remains that these neither present any very salient points for the differentiation of the species nor indications as to with which form they are most closely related. Therefore it seems advisable to bestow a distinguishing name, at least provisionally on this race, which I therefore propose should be known as *T. gymnesicus*, sp. nov.

It is thought that a brief description of the chief specimens obtained may be of use and interest.

Description of Specimens.

Unfortunately no portion of the skull was recovered and only a single cervical vertebra of moderate size and in a very bad state of preservation.

Carapace.—This is represented by three fragments; one of these is evidently part of a left anterior marginal plate and in shape resembles those of the Madagascan *T. grandidieri*, sloping gently down and having a rounded edge, in marked contrast to some of the earlier Egyptian forms with sharp-edged and abruptly recurved marginal plates. The Menorcan example, which is 17 cm. in length, is slightly convex in outline, and at one end retains part of the line of junction with the next plate. It attains a thickness of 33·5 mm., thus surpassing by some 13 mm. any among a number of fragments from the Maltese caves.[3]

A second Menorcan specimen, still partially embedded in the hard red matrix, is convex in outline and attains a thickness of 27 mm. It is probably part of one of the neural plates, and indicates that there was no great difference in the thickness of the various portions of the carapace, such as obtains in that of some species in which the dorsal area is very much thinner than the periphery.

A third fragment of plate is only 18 mm. thick.

[1] Rothschild, *Novitates Zoologicæ*, vol. iii, p. 85, 1896.
[2] *Gigantic Land Tortoises*, London, p. 24, note, 1877.
[3] Leith Adams, Quart. Journ. Geol. Soc., vol. xxxiii, p. 178, 1877.

Dermal Ossicles.—Two small specimens were obtained from Menorca: one, somewhat ovoid in outline, measures 87 mm. in circumference and about 10 mm. in thickness; it is convex on one side and almost flat on the other. The second example is more irregular in shape; both are highly mineralized, and their bony structure is of much closer texture than is the case in the ossicles of *T. grandidieri*, a number of which are included in the collection of the British Museum (Nat. Hist.). These ossicles occur in *T. perpiniana*, and are found chiefly on the fore-limbs according to the restoration given by Professor Depéret,[1] who lays some stress on their presence, shape, and arrangement, which he cites as among the chief characteristics distinguishing this species from the existing giant races in which they are said to be absent. It may be mentioned that they are present in the gigantic tortoise from the Miocene of Mont Lebèron.

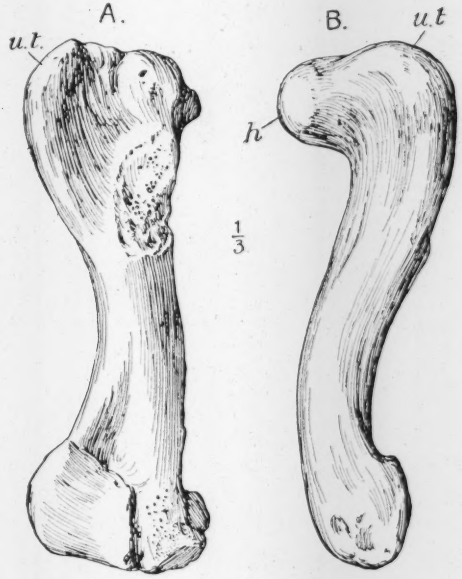


FIG. 1.—Left humerus of *Testudo gymnesicus*. A. ventral surface; B. post-axial surface. *h.* head; *u.t.* ulnar tuberosity. ⅓ nat. size.

Humerus.—Five specimens of this limb-bone are included in the collection, two belonging to the left and right sides being in a fair state of preservation. These are large and very similar, though they evidently did not belong to a single individual; they are perhaps of more slender proportions than those of *T. grandidieri*. In both the surface of the distal end of the bone is considerably worn and

[1] *Les Animaux Pliocènes du Roussillon* (Mém. Soc. Géol. France), 1890, pp. 150–4, pls. xiv, xv.

damaged. The curvature in these examples is pronounced, but not nearly so marked as in the smaller *T. pyrenaica* or in *T. perpiniana* from the Pliocene deposits of Roussillon.

In the left humerus (Fig. 1) the radial process and the region of the ectepicondylar canal are wanting; the head is prominent, but on comparison was found to be considerably smaller than in a Madagascan specimen, with which, on the other hand, it agrees in the absence of any excavation between the head and the ulnar process. Its greatest length is 21·3 cm. and the smallest part of the shaft is about 10·4 cm. in circumference. In the right humerus the head and ends of the radial and ulnar processes are missing; the circumference of the shaft is 9·3 cm., while the greatest width at the distal extremity is 7·3 cm.

A third example consists of the imperfect distal extremity of the left humerus, which must have been that of an individual of about half the size indicated by the specimens described above. Two fragmentary specimens probably represent portions of the distal extremities of humeri which would have greatly exceeded in size any of the other corresponding bones in the collection. One shows a thickness of 4·4 cm., as compared with 3·5 cm. in the right humerus described above, while the second fragment was probably part of a bone of still greater dimensions. There is no example of this limb-bone in the earlier collection from Malta, but two are included among the casts recently acquired. One of these (B.M. $\frac{R}{3967}$) is of the right side, and is in an almost perfect state of preservation except for the loss of the greater part of the ulnar process. Its greatest length is 23 cm., and the smallest circumference of the shaft is 11·4 cm. and the greatest width of the distal extremity is 8·7 cm. These measurements are only slightly greater than those of the two well-preserved specimens from Menorca. The second specimen is the very large one already referred to.

It may be worth mentioning that in the British Museum (Nat. Hist.) collection there is an isolated specimen of this limb-bone from Madagascar (R 2104) which is truly colossal, and differs as much from the remainder of the collection from that island as it does from the Menorcan examples. Its proportions may be realized from its greatest length, which is 35 cm., the smallest circumference of the shaft 19·1 cm., and the greatest width of the distal extremity 14·4 cm. These measurements indicate a creature surpassing in size any other known Pleistocene form.

Radius.—The collection includes two distal extremities of this limb-bone, neither of very large dimensions. The smaller is of the left side, and, though stouter, in general outline it resembles the smaller of two specimens in the Maltese collection, especially in the angle of the ulnar articulation, which is very different in some other species. Its circumference at the break is about 47 mm., and the greatest thickness of the carpal articulation is 14 mm. The preaxial angle is missing. The second example is of the right side and is broken off a short distance above the ulnar articulation. It has a circumference of 52 mm. at the break and a greatest thickness of hardly more than 18 mm. A very large radius of the right side in

Mr. Tagliaferro's collection has a greatest length of 16·8 cm. and an antero-posterior width of the proximal extremity of 7·3 cm.

Ulna.—This limb-bone is represented in the Menorcan collection by one specimen only. The olecranon is missing, otherwise it is almost entirely preserved, but its outline is somewhat obscured owing to its being still attached on its post-axial aspect to the hard red matrix.

It is of the right side, and is 85 mm. in length from the highest point of the humeral articulation. The pre-axial surface of the bone is slightly damaged, but it is evident that there can have been only the slightest, if any, roughening for the distal articulation with the radius. This roughened surface is very distinct in the cast of a large specimen (R 3969) from Malta. The proximal radial articulating surface is about 21 mm. wide and that of the humeral articulation 23 mm.; there is a pit, probably for the attachment of a ligament, at the middle of the shaft on its pre-axial edge. The bone is considerably twisted and the pre-axial border much curved. Though smaller the Menorcan ulna resembles that of *T. grandidieri* in general conformation, except that its distal extremity is squarer in outline and the lower half of the post-axial border more prominent.

Pelvic Arch.—This is represented by an imperfect right innominate bone and two ilia, all of considerable size, though far from equalling the proportions of some of the other bones from Menorca. The Spratt collection from Malta only includes three fragments of this bone referred to *T. robusta*, none of which are sufficiently preserved to be of assistance for comparison. Besides this there is in the national collection a cast (R 3972) of the acetabular region of a very large individual also from Malta. The greatest diameter of the acetabulum is 9·3 cm.

Neither of the Menorcan ilia is in a good state of preservation: that of the right side is 11·9 cm. in extreme length and has a greatest thickness of 2·6 cm., though both these measurements must have originally been slightly more. In that of the left side the acetabular articulating surface is present and has a width of 3·4 cm. This example is still adhering to the matrix on its ischial border.

The right innominate bone is still partially embedded in the matrix and is considerably damaged, the upper half of the ilium being wanting and the pubis and ischium in a fragmentary condition. The obturator foramen is ovoid in shape and has a greatest diameter of about 3·9 cm. The pelvis differs considerably among the gigantic tortoises; in *T. ponderosa*[1] the lower portions of the pubic bones are much extended, together forming a beak-like process. This character does not obtain in that of *T. elephantopus*,[2] which the Menorcan example seems to closely resemble.

Femur.—The collection includes an imperfect specimen of small size and the proximal ends of three others, none of which approach in size the humeri described above. The small femur is of the right side and has a total length of 11 cm., and the smallest circumference of the shaft is 5·5 cm. Part of the distal extremity is missing and the proximal end is much damaged, but it can be seen that there is no intertrochanteric notch and probably none between

[1] Günther, op. cit., pl. xviii. [2] Ibid., pl. lii.

the greater trochanter and the head. The largest of the three proximal ends (Text-fig. 2) is very fragmentary, but shows that both upper and lower aspects of the shaft were much flattened.

In the second most of the greater trochanter is missing, but there was evidently no intertrochanteric notch, nor any more than the shallowest groove between the head and the greater trochanter.

The specimen shown in Fig. 2 (2, 2*a*) is of the right side and small in size. The shaft is slender, its circumference being only 4·5 cm. a short distance below the head, which has a largest diameter of

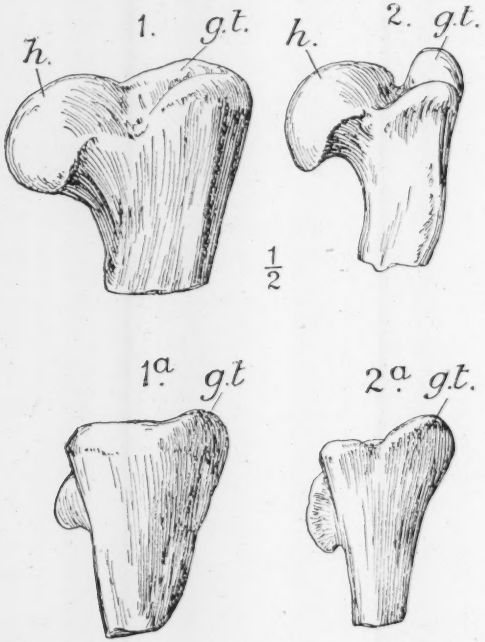
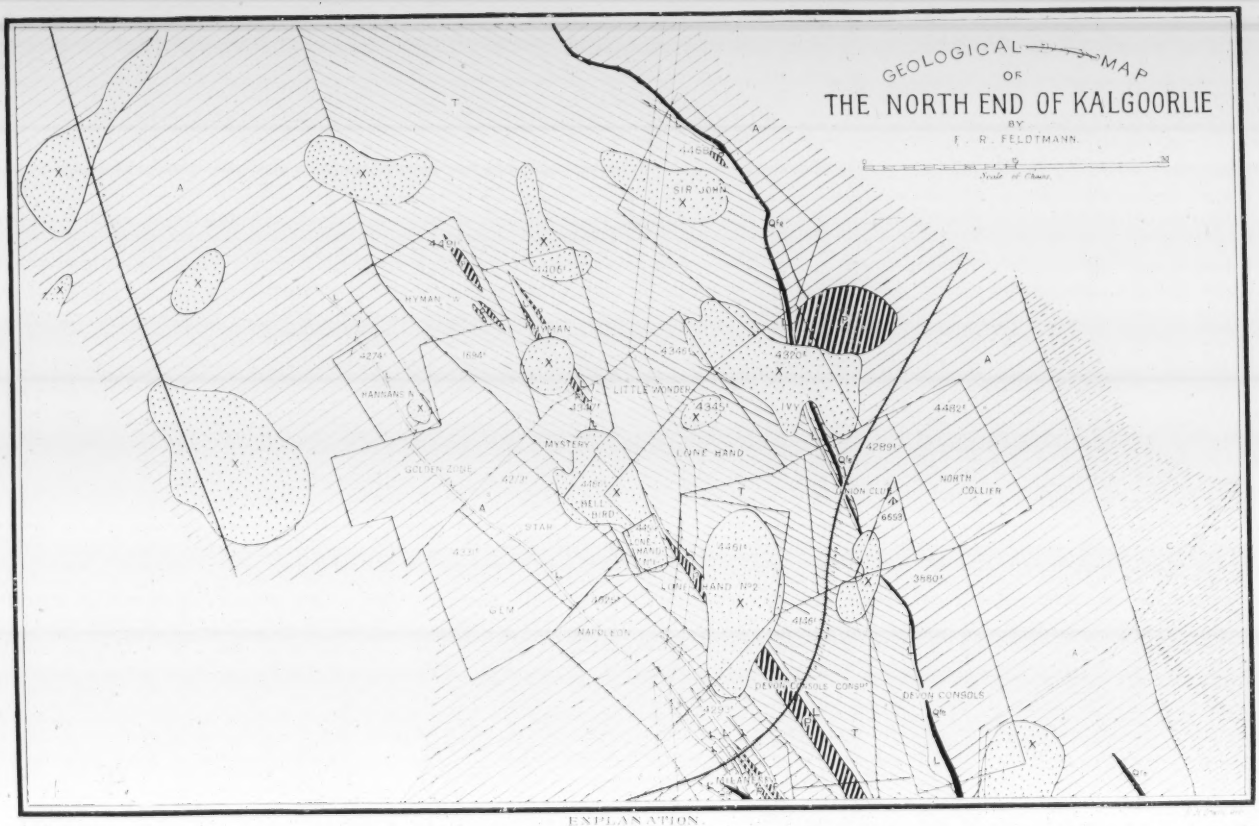


FIG. 2.—Upper ends of two right femora of (?) *Testudo gymnesicus*. 1, 2, anterior face; 1*a*, 2*a*, ventral face. *h*. head of femur; *g.t*. great trochanter. ½ nat. size.

barely 3 cm. It differs from the other examples in the greater trochanter rising considerably above the lesser, in the presence of a shallow groove between the two trochanters, and a deeply excavated one between the greater trochanter and the head. Though very inferior in size, in these other respects it is not unlike the proximal end of a femur of *T. robusta* in the national collection.[1] The difference between the Menorcan specimens is well shown in Text-fig. 2. In all three the pit between the head and the trochanters is of considerable size and depth, though in the second this is only inferred as the hollow is still partially filled with matrix.

[1] Described and figured by Leith Adams, Quart. Journ. Geol. Soc., vol. xxxiii, pl. v, figs. 4, 4*a*, 4*b*, 1877.



To illustrate paper by Mr. R. A. Farquharson on the Petrology of North Kalgoorlie.

Tibia.—Owing to its imperfect state of preservation one specimen obtained presents some difficulty in determination, but it is thought to be the proximal end of a tibia. It belongs to the right side and has both the anterior and posterior tuberosities damaged. It is of considerable size; the shaft is flattened posteriorly, and its circumference at the break is nearly 10 cm. The width of the femoral articular surface is 69 mm. in spite of the edge of the external tuberosity being missing. This measurement is not quite attained by any of the corresponding bones of *T. grandidieri* in the national collection, and greatly exceeds that of the larger specimen in the earlier collection from Malta. Among the casts presented by Mr. Tagliaferro is that of a nearly perfect right tibia of much larger proportions than any of the above.

Phalanges.—The collection includes an almost perfect specimen of a small terminal phalanx; it is comparatively wide for its length, measuring 16 mm. across by 27 in length. The constriction at its articular end is more marked than in the specimens from Malta.

III.—Notes on the Petrology of a portion of the North Kalgoorlie Field.[1]

By R. A. Farquharson, M.A. (Oxon.), M.Sc., F.G.S.,
Petrologist to the Mines Department of Western Australia.

(PLATES V–VII.[2])

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I. Introduction.

THE majority of the numerous papers that have already been published on the petrology of Kalgoorlie have dealt with the subject only in a more or less general way. Few investigators have hitherto devoted their energies to the study of one portion of the field, and even Larcombe, whose main thesis[3] seems to have been the study of the Golden Mile, has chosen an area in which owing to the magnitude and depth of the lode formations, and the consequent chemical and thermodynamic alterations, definite clues as to the original rock types could hardly be expected to remain, since there can be no doubt that in petrology, as in stratigraphy, much light can occasionally be thrown on the most difficult portions of a field by the study of the outlying portion. It has therefore been with considerable interest that the investigation of the North End has been begun.

[1] By permission of the Director of the Western Australia Geological Survey.
[2] [Plates VI and VII will appear in the concluding part of this paper.—Ed.]
[3] *Geology of Kalgoorlie.*

It is held from facts that can be established in this and adjoining areas, with regard both to the lodes and the country rocks, that the changes taking place progressively towards the most complex portions of the field can be gradually traced, and identification made on reliable evidence that may not be forthcoming in the latter. It may, of course, happen that there are several points even at the beginning that have to be left undecided, and we shall see that this is certainly the case in the North End, but it is hoped that the investigation of the succeeding portion of the field will clear up the difficulties and obscurities surrounding these.

Though the writer was enabled to spend a few days going over the ground, the field work has been entirely done by Mr. Feldtmann, and the specimens representative of the area were largely collected by the same officer, but the collection has been supplemented by the specimens already in the Survey Museum which have been taken from time to time by other officers of the department past and present, viz. Messrs. Beecher, Campbell, Gibson, and the Government Geologist Mr. A. Gibb Maitland.

2. Previous Literature.

Practically nothing has been written so far on the North End. Gibson[1] makes mention of it in places, but only in the most general way. Larcombe[2] dismisses it with a reference to a plan and section.[3] He does not mention the appearance of any porphyrite (keratophyre), though he notes that amphibolites occur at the North End.

3. Classification of the Rocks.

Altogether about sixty specimens have been sliced and examined.[4] In the main, as regards colour, the rocks fall into two broad groups: (*a*) those of a yellowish or brownish tint, and (*b*) those of a greenish tint, which varies from greyish to deep green. The former are, as a rule, hard, but the latter[5] are all in the soft, somewhat clayey rocks with a more or less pronounced soapy feel. Much difficulty has been encountered in the study of the specimens. With very few exceptions—some of the porphyrites and a few doleritic or gabbroid rocks—the whole collection consists of specimens that have been intensely altered, in some cases so altered that no trace whatever of original structures now remain. In most cases only diligent search, with high-power lenses, has enabled such clues as remains of felspars and pseudomorphs and felspars and ferro-magnesians to be detected.

[1] Geol. Soc. W. Australia, Bulletin 42.

[2] Loc. cit.

[3] Plate v, Geological plan and section of the Tea Gardens.

[4] Of those of this number that were obtained by previous collectors, two, viz. Nos. 2918 and 11096, find no counterparts among Mr. Feldtmann's collection. No. 2198 was obtained from the extreme north-west of the area und r consideration, and from a dump so weathered as to yield no specimens of any service. The locality from which 11096 was brought has been noted in such vague terms as to render it impossible now to trace the specimen in the field.

[5] With the exception of Nos. 12322 and 12324.

and frequently, even when they have been discovered, there is no residue of the original rock structure. However, since very similar chloritic planes may result both from an acid rock with ferro-magnesians and from a basic one, if neither the character of the felspar can be determined, nor any original structure be discovered, discrimination between the two chlorite phases becomes almost, if not quite, impossible, even with recourse to chemical analysis. By careful study and correlation, however, the following classification has been drawn up:—

A. The quartz-keratophyres, with or without phenocrysts of hornblende, and with or without tourmaline.
B. Those rocks most probably derived from gabbros or dolerites.
   1. Epidiorite group.
C. The talc-chlorite rocks, derived from amphibolitic or other basic rocks, but with indistinct, if any, remains of structure.
D. Rocks of doubtful origin.
   1. The 'fuchsite' rocks with or without tourmaline.
   2. Rocks of possible plutonic origin.

As a rule the identification of rocks belonging to group A has presented no great difficulty, but there are cases in which a determination cannot be made with certainty. Such a case is presented by 12372A. This specimen is a greyish-green rock that is characterized by a considerable amount of scaly chlorite, granular and idiomorphic carbonate, and remains of felspars, which raises doubts as to whether it should be classed as a highly chloritic phase of the porphyrite or as a phase of the dolerite or gabbro. It has been shown recently by Kirk[1] how in the neighbourhood of veins—in the particular case copper veins—a rock as acid as a hornblende granite has developed both a chloritic and a sericitic phase. Describing the latter, Kirk remarks: "Grading laterally from the fresh granite is a chloritised facies having many characteristics analogous to those of propylitised rocks. . . ."

In 12372A, moreover, in the case in which twinned felspar remains admit of measurements of the extinction angles, the species appears to be either albite or albite-oligoclase. The crystals, too, do occur in forms strongly suggestive of their being phenocrysts. The comparatively large amount of chlorite, however, and the large amount of idiomorphic carbonate, with patches of rutile, suggest a relationship with the more basic dolerites.

Again, in the area under review, there are several specimens[2] which consist now of a fine granular mixture of quartz, sericite, calcite, sometimes fine scaly chlorite, and some doubtful particles of leucoxene. These rocks, since no trace of original structure is discernible, have been classed amongst those of doubtful origin (see later on). Now, Kirk, in the paper already referred to, treating of the origin and significance of sericite states[3]: "All the above references indicate that where sericite can be certainly identified,

[1] *Economic Geology: Mineralization in Copper Veins at Butte, Montana*, vol. vii, No. 1.
[2] i.e. 12381, S. 610, S. 188.
[3] Op. cit., vol. vii, No. 1, p. 57.

it becomes a useful corroborative criterion in the interpretation of previous hydro-thermal high pressure conditions. It has been observed to be always a secondary mineral not adjusted to the belt of weathering. The mineral develops typically by hot spring action. . . ."

Further, in his description of the rocks of Cape Colville Peninsula, New Zealand,[1] Professor Sollas describes specimens that were sent to him from localities very rich in rocks of andesite and porphyrite character as quartz-sericite rocks of indeterminable origin. If it is borne in mind that tourmaline is quite prevalent in the North End, except in the lodes, and that its formation is generally held to be due to solfataric or pneumatolytic action, there appears at least a possibility that the specimens are the altered product of the quartz-keratophyre rock.

Again, in some instances, no clear line of demarcation can be drawn between groups B and C. By alteration and subsequent elimination of the felspar, and conversion of the augite to hornblende and chlorite, gabbros and dolerites may pass easily into rocks indistinguishable from some of those of C. Since the change from augite to hornblende by the action of dynamic agencies is now recognized to be a common one, the intermediate stage of diorite and amphibolite may also have occurred, so that some of the altered rocks may show resemblances more to the amphibolites than to the original gabbros or dolerites. The bases of distinction that have been adopted between the two groups are more or less arbitrary, viz., the presence or absence of the remains of felspars, and a recognizable structure.

4. Description of the Rocks.

A. The Quartz-Keratophyre.

1. *General.*

Of the field relations of this rock little can be said with certainty. Nowhere does it outcrop at the surface. Though specimens have been collected from various dumps, in most cases the shafts associated with these dumps are now inaccessible. In the few instances in which the rock is found in the mines, it occurs in association with talc-chlorite rocks, but owing to the great amount of alteration of various sorts its relations cannot be made out with any degree of clearness. According to Mr. Feldtmann, however, there are a few instances in which it does occur in tongue-shaped and dyke-like masses, as at the 120 ft. level, south shaft of G.M.L., 4406 E., Hyman, and consequently is to be regarded on field occurrence more as an intrusive porphyrite than as an andesite.

Characteristic of the rock-mass is its peculiar blotchy or jointed structure. In hand-specimens from yellowish-brown to dark brownish-grey the specimens are, for the most part, comparatively fresh, of medium grain, and with occasional small phenocrysts of felspar. In the darker varieties small green spots are frequently observable, while in all varieties are minute brownish-red patches,

[1] *Rocks of Cape Colville Peninsula*, vol. i, pp. 135–7.

which prove, on examination, to be decomposed pyrites or ferro-magnesian crystals. Especially noticeable in a few samples, e.g. 12331A, are rather lenticular patches, sometimes 1½ inches in length and ½ in. in width, composed of a pale-green chlorite, some limonitic iron-ore, and strings of very fresh needles of dark-green tourmaline. In such an advanced stage of alteration are these patches that it is impossible to say definitely from the evidence available whether they are original or represent xenoliths that have been altered partly by ordinary chemical agencies and partly by a kind of pneumatolytic action. It certainly would appear that the keratophyre when near the temperature of consolidation, but still more or less viscous, had enclosed within its mass fragments of greenstone, and that the tourmaline had been produced as a contact-metamorphic product by vapours containing boron associated with the intrusive. On the other hand, not only does tourmaline occur in some of the slides fresh and with no connexion with chlorite, but the felspars and the rock itself in these cases are quite fresh. Unless, therefore, the specimens have been collected from the margins of the keratophyre, and the tourmaline is, in consequence, due to a partial impregnation of the rock by boric vapours, it is difficult to see how in the latter case the mineral can be regarded as other than original.

Regarding the occurrence of tourmaline, Clarke[1] states: "In igneous rocks it seems to have been produced by fumarole action, and not as a direct separation from the magma."

Van Hise writes[2]: "Tourmaline rather frequently occurs in the marbles and in the calcareous schists; it also has a rather widespread occurrence in granites, gneisses, etc. In these rocks it frequently occurs in such relation to dykes of igneous rocks, especially of pegmatites, as to suggest that its development is promoted by contact action. Because of the boron, tourmaline has generally been regarded as evidence of fumarole action. Certain it is that boron is not usually a constituent of the ordinary sediments, and to account for this element would seem to require its introduction from an outside source, either by gaseous or by aqueous solutions."

The occurrence of the mineral in the North End is not restricted to the keratophyre. Indeed, according to the field evidence the mineral is especially common in the lode formation, which consists of kaolin and sericitic material seamed with quartz and quartz-tourmaline leaders. Moreover, in the Mystery Lode in the altered keratophyre contiguous to the lode material, small nests of the mineral have been found which appear to be partially moulded by gold. From this it is probable that the gold is not contemporaneous with the tourmaline, but has been formed at a later date by percolating solutions. Further, as will be seen later on, there are specimens of the quartz-carbonate-fuchsite rock, apparently on the margin of which occur strings of tourmaline.

Most noteworthy of all are specimens 12331B and 12237. These are both from the same locality, viz. G.M.L., 4458 E. They are both light-coloured rocks with a faint reddish tinge, and both show distinct

[1] Clarke, *Data of Geo-chemistry*, p. 347.
[2] Van Hise, *Treatise on Metamorphism*, p. 326.

evidences of shearing. Along the shear planes there has been sometimes a deposition of dendritic manganese oxide. The most important feature about them, however, is the presence, particularly in 12331B, of numerous irregular greenish patches, apparently embedded in a keratophyre mass. These patches, which are soft, very minutely scaly, and with a faint lustre, vary in size from ¼ up to 1 inch in length and breadth, and are generally, though not always, flattened parallel to the line of shearing. They are much weathered, and apparently consist wholly of minute scales of chlorite. Owing to their presence, the rock has at first sight the appearance of a breccia, but a careful examination of the material shows it to be without doubt the keratophyre.

The question arises as to what is the origin of the green fragmentary forms. Both rock specimens were obtained from the same dump, but access to the shaft associated with it was impossible. An examination of the dump, however, shows that from the one shaft there have been thrown out both the porphyritic rock with the green forms and a very much weathered soft-green schist. It proved impossible to obtain anything like a fresh specimen of the latter, but from an examination of a slice of the most suitable material obtainable it was identifiable as a fine-grained chlorite schist. Moreover, though all the rocks are extremely weathered, there seems little doubt that the green fragments and the chloritic schist are identical. Further, the green forms are all essentially of an angular nature; they show no trace of crystal outline, they are themselves schistose.

Taking these facts in conjunction with the sheared nature of the keratophyre 'matrix', the most feasible interpretation of the occurrence is undoubtedly that the green fragments are true xenoliths. Owing to the decomposed nature of the rock, however, the question is a doubtful one. There is, of course, another interpretation, namely, that the enclosures owe the circumstances of their occurrence to the shearing of the keratophyre—that they have, in fact, been sheared into it. It must be admitted that in no case does any assimilation of the chloritic schist and the 'matrix' seem to have taken place; also the majority of the enclosures appear flattened parallel to the plane of shearing. On the other hand, in specimen 12237, in which the shearing effect is not so pronounced as in 12331B, the enclosures are sometimes only partially flattened, and in places appear to be nearly normal to the shear plane. In addition, though there are numerous green particles scattered through the rock, no granulation of the larger xenoliths can be observed, and there is little drawing out of the latter into lenticular forms.

2. *In Detail.*

The external characteristics have already been given. In some of the freshest specimens green spots are visible which are not referable to tourmaline, but which in section prove indisputably to be chloritized phenocrysts of hornblende.

Numerous determinations have previously been made of rocks more or less identical with these, and such names as felspar-porphyry, porphyrite, felspar-porphyrite, etc., have been given to them.

Several facts, however, have hitherto completely escaped notice. In the first place, while the rocks in general are undoubtedly composed almost entirely of felspar, and the mineral occurs frequently as phenocrysts, there are quite a number of instances in which no phenocrysts are present, and the rock is apparently wholly made up of small rectangular and columnar laths of the mineral, without, however, any 'flow' or 'trachytic' structure. Moreover, the character of the felspar is peculiar. Both measurements of the extinction angles on albite lamellæ and chemical analysis show that the mineral is particularly rich in soda; indeed, the percentage of lime in the analysis is so small that it can no doubt be all accounted for by the presence of (decomposed) ferro-magnesians. No potash whatever appears in the analysis.

Further, there are indisputable evidences of the former presence of phenocrysts of hornblende: six-sided crystal forms showing prismatic angles which measured 125° and 55° have been observed in several instances, and though, owing to chloritization of the mineral, the usual prismatic cleavages are not observable in cross-sections, the six-sided form, so common in cross-sections of hornblende, and to a less extent the occurrence of rectangular and rhombic longitudinal sections, leave no doubt as to the identity of the mineral.

As will shortly be shown, a comparison of the composition, characters, and structure of the rocks establishes their identity with that group which Rosenbusch calls quartz-keratophyres, but which also appears elsewhere as albite-porphyrites. In many ways they agree also with varieties of quartz-andesite, but, though it was impossible to prove the presence of fluid cavities in the quartz, there is no indication of any glassy base; the felspar is evidently albite, and, according to the field evidence, as has been stated, the rocks are at times distinctly intrusive as tongues and narrow dykes.

(*a*) *The Porphyritic Type.*—12331A, 12331c. G.M.L., 4406 E., Hyman.

M.C.[1] A grey rock with faint reddish tinge, and with one enclosure of large size and several of small size, all containing strings or small nests of tourmaline needles.

S.[1] Minerals observed: felspar, quartz, chloritized hornblende, muscovite, brown and black iron-ore in crystals and grains, chlorite.

In ordinary light the section shows scales and flakes of green pleochroic chlorite, brown and black grains of iron-ore, and various sections of chloritized phenocrysts in a clear or slightly brown-stained ground (Pl. VI, Fig. 1). The chloritic sections occur in rhombic, rectangular, and clearly six-sided shapes, and without any doubt represent original hornblende. No tourmaline was seen in the particular section examined, though its presence was visible to the eye in isolated spots in the rock.

Under crossed nicols, besides the chloritized phenocrysts, appear large idiomorphs of fresh, often minutely twinned felspar in a ground-mass of minute laths of the same mineral, and small plates and platy aggregates of quartz (Pl. VI, Fig. 2). Measurements show

[1] M.C. = macroscopic characters; S. = section.

that the felspar is albite or albite-oligoclase. The ground-mass consists of innumerable fine laths of twinned felspar with, in places, an approach to felted structure, a fact which tends to show that the rock consolidated sensibly under atmospheric pressure conditions. Quartz occurs not only in minute plates, but also in mosaic aggregates and in one or two rather large forms, which are, however, quite without definite outline. In some places the felspar phenocrysts present corroded margins as if the ground-mass had reacted on the phenocrysts. In other cases they appear to be partially replaced by clear quartz and muscovite.

To settle all doubt as to the nature of the predominant mineral a chemical analysis of the rock was made in the Survey laboratory, with this result—

	Per cent.		Per cent.
SiO_2	69·02	*Brought forward*	78·80
TiO_2	·57	MgO	2·63
CO_2	·14	MnO	·09
P_2O_5	·28	FeO	1·90
$H_2O + X$	1·02	Fe_2O_3	·58
K_2O	*nil*	Al_2O_3	15·92
Na_2O	7·48	FeS_2	·11
CaO	·29	H_2O	·28
	78·80	Total	100·31

The absence of K_2O and the high percentage of Na_2O with the low percentage of CaO show conclusively that the species is highly sodic, and mostly, if not wholly, albite. Moreover, the high silica percentage bears out the identification of quartz in the ground-mass.

This analysis was compared with those of some rocks of other localities:—

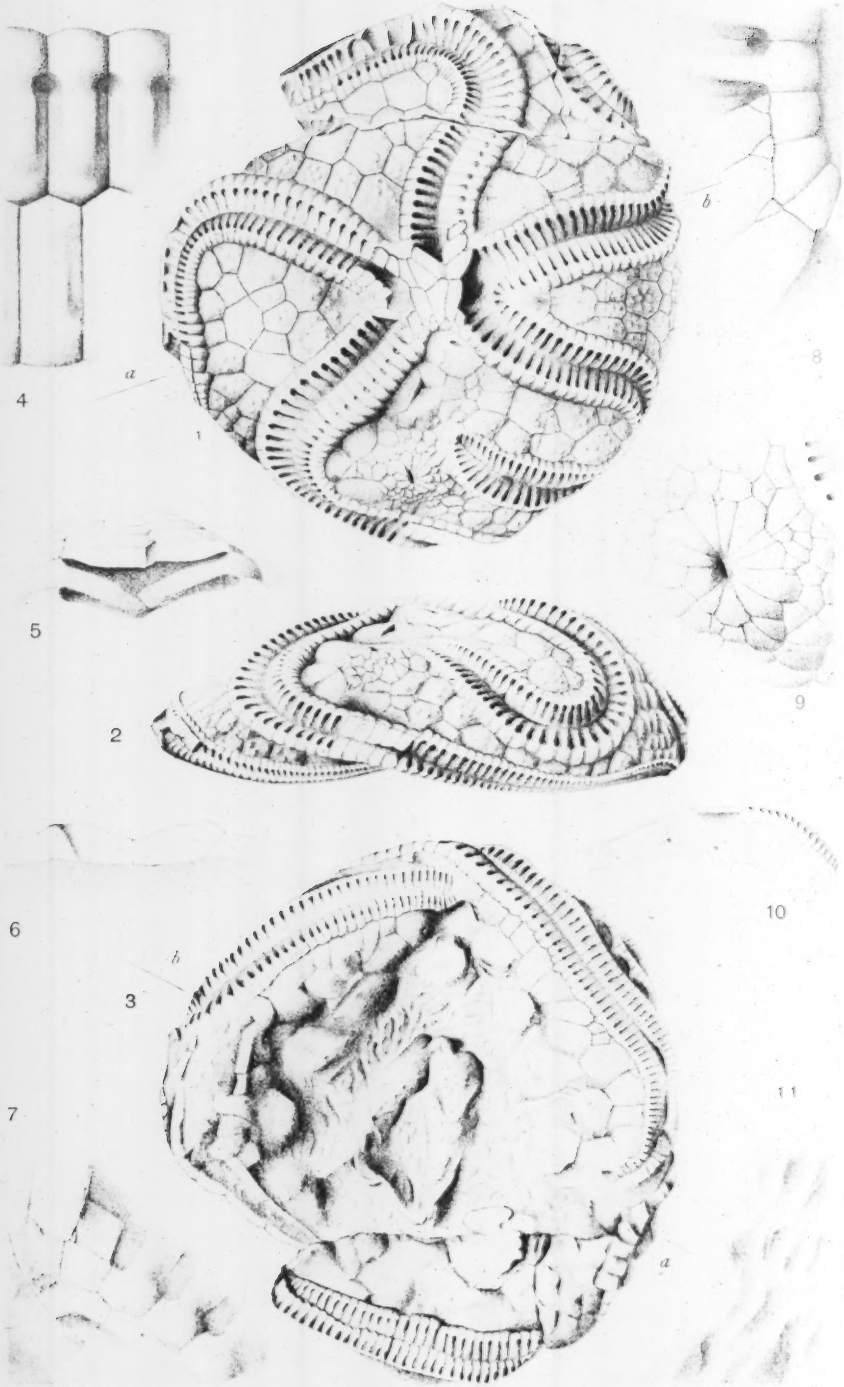
	1	2	3	4	5
SiO_2	68·04	67·90	72·24	72·34	69·02
TiO_2	—	·24	·41	—	·57
Al_2O_3	16·14	14·36	13·85	14·07	15·92
Fe_2O_3	4·32	4·36	1·45	2·92	·58
FeO	·97	1·44	1·86	—	1·90
MnO	—	·32	·12	—	·09
MgO	1·02	·22	1·10	1·27	2·63
CaO	·32	1·34	3·40	·41	·29
Na_2O	7·62	6·89	4·43	6·28	7·48
K_2O	·58	1·85	·39	1·13	*nil*
H_2O	1·27 [1]	1·52	·86	1·41	1·02
P_2O_5	—	—	·10	—	·28
Total	100·28	100·44	100·21	99·83	100·31 [2]

1. Quartz-keratophyre (Rosenbusch, *Gesteinslehre*, 1910, p. 329).
2. ,, ,, ,, ,,
3. Quartz-diorite-porphyrite (Osann, *Beiträge zur chemischen Petrographie*, p. 87).
4. Keratophyre (brown), Osann, p. 120.
5. Analysis of 12331A re-quoted for comparison.

(*To be continued.*)

[1] Glühverlust.

[2] Includes CO_2, FeS_2, and H_2O.



G. C. Chubb ad. nat. del. London Stereoscopic Co.

EDRIOASTER BIGSBYI

IV.—Studies in Edrioasteroidea.[1] IV. The Edrioasters of the Trenton Limestone.

By F. A. Bather, M.A., D.Sc., F.R.S.

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(PLATES X-XIV.)[2]

Previous History.

EDRIOASTER bigsbyi was first made known by E. Billings in June, 1854,[3] and was referred by him, though with some doubt, to *Agelacrinites*. He gave no specific name, but regarded his fossils as identical with the specimen found by Bigsby at the Chaudière Falls and described by G. B. Sowerby in 1825 (see Study III), and as "almost identical with *A. Buchianus*" of Forbes, 1848 (see Study II). This series of papers by Billings contains several important observations and reasonings not reproduced in those later more official publications of his to which alone subsequent writers seem to have gone for information. From the original account it is clear that the specimens there called *Agelacrinites* were the same as those which Billings described in 1857, under the name *Cyclaster bigsbyi*.[4] The misapprehension that caused Billings to apply to his new species the trivial name *bigsbyi* has already been dealt with in Study III; the species has nothing to do with the specimen found by Bigsby. In 1858 Billings discovered and pointed out his error, and, realizing further that the generic name *Cyclaster* had been taken by G. Cotteau for a sea-urchin a few months before his own use of it, he redescribed the species under the name *Edrioaster bigsbyi*.[5] The independence of the genus itself was denied in 1860 by E. J. Chapman, who referred the species back to *Agelacrinites*.[6] The textbook writers, however, generally accepted *Edrioaster*, and no change was made in either name or description until Professor Haeckel in 1896 thought fit to alter the name to *Edriocystis*.[7] Neither the nomenclatoral nor the taxonomic vagaries of Professor Haeckel won any favour, and it is needless to allude further to him or to other writers who shared his ignorance of the facts but not his imagination. In that category I do not include Professor O. Jaekel, but even he, in his *Stammesgeschichte der Pelmatozoen* (1899, p. 46), contented himself with the information and figures published by Billings in 1858, apart from such hints as he could glean from the manuscript of my then forthcoming Study II.

[1] Studies I, II, and III were published in the Geological Magazine for December, 1898, May, 1900, and December, 1908. Plates X and XI of the present Study were drawn in 1900, and diagrams made from the specimen represented in Plate X have been published by me in 1900, 1901, 1902, and 1911. The completion of the present paper has unfortunately been delayed by the pressure of official duties and other scientific work.

[2] [Plates XIII and XIV will appear with the continuation of this paper in the April Number.—Ed. Geol. Mag.]

[3] Canad. Journ., vol. ii, pp. 271–4, figs. 10–12.

[4] Rep. Progress Geol. Surv. Canada, 1853–6, p. 293, Toronto, autumn of 1857.

[5] Canad. Org. Rem., dec. III, p. 82, pl. viii, figs. 1, 1*a*, 2, 2*a*, June, 1858.

[6] Canad. Journ., N.S., vol. v, p. 364.

[7] "Amphorideen und Cystideen," pp. 117–8, Festschr. f. Gegenbaur, 1896.

In brief, then, from the time of Billings down to the end of last century, the genus *Edrioaster* remained most imperfectly, not to say incorrectly, apprehended. Its importance was obvious, but I did not dare to introduce it into any system of classification or any theoretical discussion without having first-hand knowledge. The opportunity for obtaining this was afforded by my friends Mr. Walter R. Billings, of Ottawa, and the late J. F. Whiteaves, of the Canadian Geological Survey, who lent me excellent material, which I was fortunately allowed to retain for several years. The need of time as well as of material has never been more obvious. Before any precise account could be written or any adequate figure drawn, it was necessary to clean and develop the specimens with the utmost patience. And here I have to acknowledge the great help rendered by my wife, who devoted months of labour to a single specimen, thus enabling Mr. G. C. Chubb to make the admirable drawings on Plate X. The information thus obtained was utilized in the diagrams and brief account of *Edrioaster bigsbyi* published in *A Treatise on Zoology*, vol. iii, Echinoderma, p. 209 (London, 1900), in the abstract of a lecture "What is an Echinoderm?"[1] and in the *Encyclopædia Britannica* articles on "Echinodermata" (1902) and "Echinoderma" (February, 1911). That specimen has been still further cleaned, several other specimens have been prepared and studied, and the results are given in the present paper.

Since 1900 the only author to pay any particular attention to my publications on Edrioasteroidea has been Mr. W. K. Spencer, who criticized some of my conclusions in his interesting paper "On the Structure and Affinities of *Palæodiscus* and *Agelacrinus*" (Proc. Roy. Soc., vol. lxxiv, pp. 31–46, pl. i, 1904), but who has since modified his objections ("Brit. Palæoz. Asterozoa": Palæont. Soc. vol. for 1913).

Material.

The holotype of *Edrioaster bigsbyi* has never yet been fixed, and should be chosen from among the original specimens described and named by E. Billings (1857). On the generally admitted assumption that these comprised the original of Billings' pl. viii, fig. 1 (1858), I hereby select that specimen as holotype. This and the other specimens described and figured by Billings in 1857 and 1858 are kept in the Victoria Memorial Museum at Ottawa. These specimens are so imperfectly preserved that Mr. Whiteaves did not consider it worth while to send them to me. He sent, however, the following three specimens, the property of the same museum, and belonging without any doubt to the same species. For convenience of reference I have lettered them A–C.

A. The original of Plate X. A theca in calcite in a matrix of very hard, grey, shaly limestone, which, when the specimen was sent me, covered the whole of its under face, but is now cleaned away. The specimen is broken into three parts by a crack across the anterior ray and another across the distal end of the right anterior ray. Part of the theca comprising the distal end of the anterior ray is missing.

[1] Journ. London Coll. Sci. Soc., vol. viii, pp. 21–33, May, 1901. Also *Che cosa è un Echinoderma?* Torino, October, 1901.

B. The original of Plate XI. A theca lying on a small block of hard, black, shaly limestone, so that only the upper face is exposed. This retains the cover-plates, which, however, are crushed in.

C. The original of Plate XIII. A theca of which the upper or oral face is covered with yellowish matrix, but of which the under or adapical face has been well exposed.

In the absence of detailed information, it is assumed that these specimens came from the neighbourhood of Ottawa, as did all those mentioned by E. Billings.

Mr. Walter R. Billings lent me the following specimens of the genus, and ultimately with singular generosity presented them to the British Museum, under whose register numbers they are here quoted.

E 16173, a medium-sized specimen, with radius *ca.* 18·5 mm. Adoral face disturbed and weathered, with hard black shale in the hollows. Adapical face worn, and obscured in centre by hard limestone matrix. Collected by W. R. Billings at Belleville, Ont., on right bank of the Moira, a quarter of a mile above the railway bridge (*E. levis*).

E 16172, a smaller specimen, with radius *ca.* 16 mm. Most of the right side is missing; rest of adoral face fairly preserved. Adapical face partly obscured by limestone and grey shale, since removed. Collected by W. R. Billings at Peterborough, Ont. (Pl. XIV, Figs. 2, 3.)

The British Museum has still more recently acquired—

E 15930, a rather large individual, radius *ca.* 25 mm., poorly preserved. Adoral face much rubbed. Adapical face coated with hard black shale, now removed. From Mount Sherwood, a suburb of Ottawa. W. R. Smith Collection, 1909. (Pl. XIV, Fig. 1.)

E 16054, a smaller individual, radius *ca.* 11 mm., preserved obliquely and therefore less flattened, in a brown, sandy, calcareous shale. From Belleville, Ont. W. R. Smith Collection, 1909.

E 15900, a rather large individual, radius *ca.* 23 mm. Adoral face fairly well preserved. Part of the adapical face exposed. Matrix a dark-grey shale. From Kirkfield, Ont. Presented by Professor W. A. Parks, 1909. (*E. levis*, Plate XII.)

Horizon.

All the known specimens are from the Trenton Limestone.

In the absence of more precise information, I take the horizon at Ottawa to be probably the limestone with shale partings which Dr. P. E. Raymond (1912[1]) assigns to his Horizon 5; but it is also possible that some specimens are from his lower Horizon 2, which is exposed in the Hull quarries. E. Billings (1854, p. 272) found "seven specimens . . . within a space of four square yards in extent, and partially embedded in the surface of a stratum of limestone. Along with them were" trilobites, crinoids, *Amygdalocystis tenuistriatus*, and a quantity of *Chætetes lycoperdon*. These, with others, were all "in the upper one hundred feet of the Trenton limestone" (p. 273).

[1] 1912, Summary Rep. Geol. Surv. Canada, 1911, p. 354.

Specimen E 15900 from Kirkfield is probably from Horizon 2, which is well developed at that place.

I have no external evidence as to the horizon of the specimens from near Belleville, or of that from Peterborough.

E. bigsbyi has also been recorded from the *Fusispira* and *Nematopora* beds, in the middle of the Trenton group, in Minnesota (N. H. Winchell & E. O. Ulrich, Final Rep. Geol. Surv. Minnesota, vol. iii, pt. ii, p. cxxiii, 1897).

General Description.

The theca has an approximately circular periphery, and a diameter varying between 20 and 50 mm. As in *Dinocystis barroisi* (Study I) and *Edrioaster buchianus* (Study II), the general shape is that of a Tam-o'-Shanter cap or a Breton béret (Text-fig. 1).

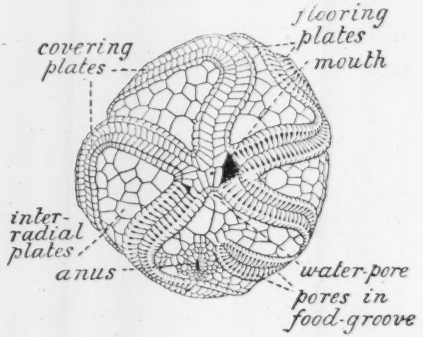


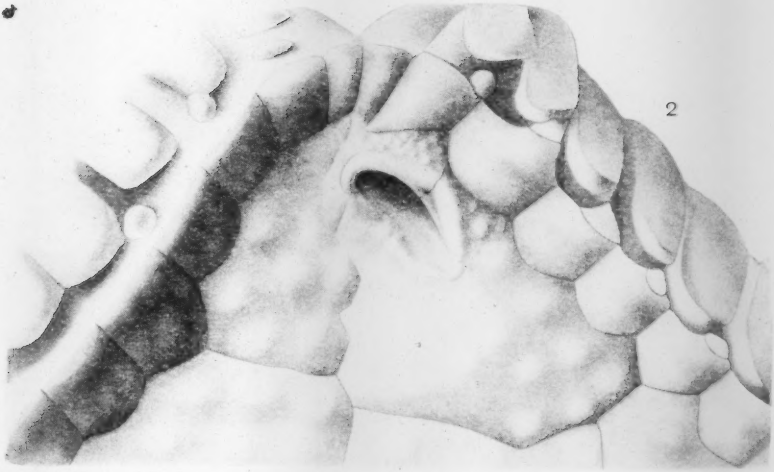
Fig. 1. *Edrioaster bigsbyi.* The adoral face, slightly restored from specimen A. The cover-plates are removed from rays I, IV, and V, but remain on rays II and III. Natural size.

The mouth is at or near the centre of the convex face, and from it five subvective grooves pass over the theca on to the concave face. Each groove is sharply curved as it approaches the periphery; the curve of the right posterior is probably always solar (= dextral), that of the others is contrasolar in the type-species. Each groove is floored by an alternating series of plates (floor-plates), and roofed by alternating movable cover-plates, one to each floor-plate. The median line of each groove is depressed to form a channel, from which branches are given off to right and left between the floor-plates. Each branch ends at a pore, which passes down the suture between the adjacent floor-plates into the thecal cavity. These pores are close to the margins of the groove, but beneath the cover-plates.

The mouth opening (peristome) is surrounded by skeletal elements continuous with the floor-plates, and is roofed by plates continuous with the cover-plates.

The thecal plates of the convex face between the rays (interradials or interambulacrals) are relatively large, irregular in shape and size, and do not imbricate.

In the posterior interradius, two large interradials, adjoining the peristome, are traversed by an elongate hydropore.



G. C. Chubb ad nat. del. Bellagamba sc.

EDRIOASTER BIGSBYI.

In the same interradius lies the anal opening (periproct), surrounded by smaller interradials.

On the concave face are seen the ends of the rays, stiffening the periphery. Within them are some irregular plates continuous with the interradials; and then a circular frame of rather larger and stouter plates. Loosely stretched across the space within this frame was a flexible integument, filled with minute plates. This integument was generally protruded round the centre in roughly U-shaped lobes, apparently five in all, but often irregular, at least in the fossils.

Detailed Description.

This is based mainly on specimen A, but measurements and occasional details are also given on the evidence of the other specimens. It will soon be manifest that specimens E 16173 and E 15900 represent a species distinct from *E. bigsbyi*, to which all the other specimens appear to belong. For this new species the name *E. levis* is proposed.

The Periphery is roughly circular, with irregular swellings and indentations formed by the rays, and varying in position according to the curvature of the rays. The circular form is sometimes further departed from, in consequence of either natural growth or post-mortem pressure, as appears from the following measurements in millimetres:—

	A	B	C	E 15900	E 16173
Sagittal diameter . .	36·2	43·5	*ca.* 37	*ca.* 40	36
Transverse diameter . .	34·5	46·4	*ca.* 37	*ca.* 40	35·6

From the periphery, the theca rises steeply at first, but soon bends adorally in a low arch; towards the adapical face it bends rapidly downwards and inwards, and turns upwards as soon as the rays are passed. When specimen A is placed on a flat surface, the theca reaches a height of 11·5 mm., exactly one-third of its transverse diameter. The adapical face is excavate to about 6·5 mm., so that the length of the polar axis is about 5 mm. The specimen does not appear to have undergone more compression along this axis than it may have been capable of effecting spontaneously during life. It is, however, probable that in life the adapical integument hung lower than it is found in the fossil, so that the height of the excavation would have been about half the total height of the theca under normal conditions. The other specimens are not so preserved as to lend themselves to exact measurement in these respects; but, broadly speaking, the larger the theca the more relatively flattened does it appear. This may be due to subsequent pressure in the plane of bedding. Contrariwise, E 16054, which exceptionally lay oblique to the bedding plane, has had its relative height exaggerated by compression. E. Billings' pl. viii, fig. 1*a* (1858) shows a section across a partly crushed specimen. If this be restored to its probable original shape, the measurements are approximately: thecal diameter, 59 mm.; thecal height, 22 mm.; height of adapical excavation, 13 mm. This is one-sixth larger than any actual specimen I have seen.

Specimens that have clearly been flattened in one or another plane show some displacement of the thecal plates, and this fact, taken together with the solidity of all thecal elements other than the apical

integument, shows that the theca as a whole was not particularly flexible.

On the Adoral or Upper Face are the five Radial Grooves, of which the course may first be traced in specimen A (Pl. X, Fig. 1). All proceed with a very slight curve to a distance of about 15 mm. from the oral pole. The antero-lateral and postero-lateral rays have the concave side of this curve turned towards the postero-lateral interradii; in other words the rays of the right-hand pair and of the left-hand pair respectively bend towards each other. In the anterior ray the concavity faces the right. That is to say, the proximal curve of the left posterior, anterior, and right anterior rays (I, III, IV) is solar or dextral, and that of the left anterior and right posterior rays (II, V) is contrasolar or sinistral. All the rays except the right posterior then suddenly bend in a contrasolar direction, and after bordering the periphery for the space of an interradius, pass on to the under surface of the theca, where they continue in the same direction for the further space of an interradius, ending near the adjacent ray (Pl. X, Fig. 3). The only exception to this regularity of these four rays is that the peripheral tract of the right anterior ray bends upwards for a short distance within the right anterior interradius (Pl. X, Fig. 1). The right posterior ray, however, bends in a solar direction, and returns on the posterior interradius, ending on the oral face at a point a little to the right of the periproct, and about 9·5 mm. from the oral pole (Pl. X, Fig. 1). In consequence of this, the peripheral tract of the left posterior ray passes across both the posterior and the right posterior interradii, and ends against the right anterior groove (Pl. X, Fig. 2).

The varying curves of the rays in this specimen A and their sharp definition give them a peculiar aspect of independent life. The width of a ray in the proximal half of its course is 5·5 mm., or slightly less when close to the peristome; where it bends, the width is 4·5 mm.; on the under side it gradually tapers to 3 mm., after which it is rapidly rounded off.

In specimen B the general shape and disposition of the rays is precisely as in A, except that the anterior ray does not begin with a solar curve, but runs straight to the main contrasolar flexure. The width of a groove in the proximal half is about 6·3 mm., but may be reduced to as little as 5·5 mm. at the bend (Plate XI).

In specimen C the adoral region is covered with matrix, but from the marginal tracts it can be inferred that the general disposition of the rays is as in A and B (Plate XIII).

Specimen E 16172, so far as preserved, indicates a similar arrangement.

In E 15930 the proximal curve of the rays is contrasolar in the left posterior, left anterior, and right posterior (I, II, V), and solar in the other two rays. The distal curve of the left posterior, left anterior, and right anterior rays is visible on the under side of the theca and is contrasolar (Plate XIV). Probably the general arrangement was as in A

E 16054 is a young individual, as shown not merely by its small size, but by the small extent of the periphery occupied by the distal

tracts of the rays, which do not stretch half-way across the interambulacrum. Owing to lateral compression, the curves are not very clearly seen. The proximal curve is solar in the right anterior, contrasolar in the right posterior ray, as in A. The distal bend is clearly contrasolar in the left anterior ray, and appears to have been the same in the others, except in the right posterior, where it is solar but cannot be traced far.

The rays in E 16054 are not only relatively shorter, but taper more rapidly than in older individuals. Thus the left anterior ray is 4·1 mm. wide in the extreme proximal region; 3·1 mm. wide at about half-way to the periphery; 2·4 mm. at the periphery, whence it rather quickly rounds off.

Specimens E 15900 and E 16173 (*E. leris*) differ conspicuously from the others in that the main distal curve is solar in all rays, and that the right posterior ray, instead of being recurved, passes along the periphery of the posterior interradius and bends round like the other rays to end on the adapical face. In E 15900 the proximal curve is solar in all rays except the left anterior (II) ray, where it is contrasolar (Plate XII). In E 16173 the proximal tract is not clearly seen in ray II; in all others the curve is solar.

Summing up the evidence before me as to the distal curvature of the rays, it appears that in all individuals that of the right posterior ray, when known, is solar, that in six individuals (A, B, C, E 15930, E 16054, and E 16172) that of all the other known rays is contrasolar, and that in two individuals (E 15900 and E 16173) it is solar. Billings (1858), pl. viii, fig. 2, also represents two rays with a contrasolar bend. Although Billings (1858, p. 83) says that the rays curve "towards the right in some specimens, and towards the left in others", I know of no evidence for a contrasolar bend of the right posterior ray, and seeing that it is solar in all of our six specimens in which the other rays are contrasolar, it is hardly likely to have been contrasolar in any other case. Neither do I find evidence for any individual ray or rays (the right posterior always excepted) bending in a direction contrary to the majority, as does the right anterior in the holotype of *Agelacrinus hamiltonensis*.

In his original account (1854, p. 272) E. Billings said that he had found seven specimens, and that in one only did "the rays turn to the right [solar] instead of the left [contrasolar]". It is therefore curious that in his "partly restored figure" 10 (p. 271) he should have represented all the rays as equably solar. This must have been a pure mistake, for Mr. Walter Billings, who kindly looked up this point for me in April, 1900, said that all the ten imperfect specimens then in the museum at Ottawa showed a contrasolar flexure. The one exception mentioned by E. Billings, further distinguished as showing the adapical face, could not then be found. Subsequently specimen C, with the adapical face exposed, turned up in that museum and was sent to me. In it the rays, though contrasolar, appear solar because seen only from the under face. This may have been the specimen referred to by E. Billings, in which case none of the Ottawa specimens would have the rays solar.

The only certain exceptions to the normal arrangement are E 15900 and E 16173, which have the rays all solar; but these, on account of yet other features, are to be separated as a distinct species, *Edrioaster levis*.

The conclusion, then, is that in *Edrioaster bigsbyi* the bend of the right posterior ray is solar and recurved on the interambulacrum, that of all the others contrasolar. In *E. levis* the bend of all rays is solar, and none is recurved. In *E. buchianus* the rays of the only known specimen have the same arrangement. The same is apparently the case in *E. saratogensis* Ruedemann, 1912. For although Dr. Ruedemann says that one of the rays (inferentially the left posterior) is contrasolar, this is borne out only by his own restoration of a specimen in which that ray is not preserved (pl. iii, fig. 3). In his fig. 2 the proximal tract of the right anterior ray has a slight contrasolar curve; but all other rays in all figures are solar or straight in that region. In *Dinocystis barroisi* and in the holotype of *Lebetodiscus dicksoni* all rays are contrasolar. The facts are summarized in the annexed table.

	Proximal.					Distal.				
	I.	II.	III.	IV.	V.	I.	II.	III.	IV.	V.
Edrioaster bigsbyi A	S	C	S	S	C	C	C	C	C	S
,, ,, B	S	C	R	S	C	C	C	C	C	S
,, ,, C	?	?	?	?	?	C	C	C	C	S
E 15930	C	C	S	S	C	C	C	C	C	S
E 16054	?	?	?	S	C	C	C	C	C	S
E 16172						C	C	C	C	S
E. levis—										
E 15900	S	C	S	S	S	S	S	S	S	S
E 16173	S	?	S	S	S	S	S	S	S	S
E. buchianus	R	R	S	S	S	S	S	S	S	S
E. saratogensis	S	S	R,S	S,C	S	S	S	S	S	S
Lebetodiscus dicksoni	C	C	R	C	C	C	C	C	C	C
Dinocystis barroisi	C	C	C	C	C	C	C	C	C	C

S = solar; C = contrasolar; R = straight.

Floor-plates.—The main description applies to *E. bigsbyi*, especially to specimen A; the peculiarities of *E. levis* are noted later.

For the whole of their length the radial grooves are floored by a double series of alternating plates, which meet in a zigzag median suture. These floor-plates are elongate at right angles to the median line of the groove, the width of each plate being less than one-third (*ca.* ·28) of its length. Their outer margins are convexly curved; their abutting margins are straight (Pl. X, Fig. 4). The plates rise

sharply up from the interradial areas, they form a rounded margin on each side of the groove, and then dip almost straight down to the median suture, where they meet at an angle of about 130° (Pl. X, Fig. 6). Near the peristome this angle is slightly less, that is to say the depression is more marked; but at the distal ends it becomes wider and almost disappears. Where the grooves bend sharply, the dip of the floor-plates on the inner side of the curve becomes steeper, and the angle therefore less. All these changes can be traced in Pl. X, Figs. 1–3.

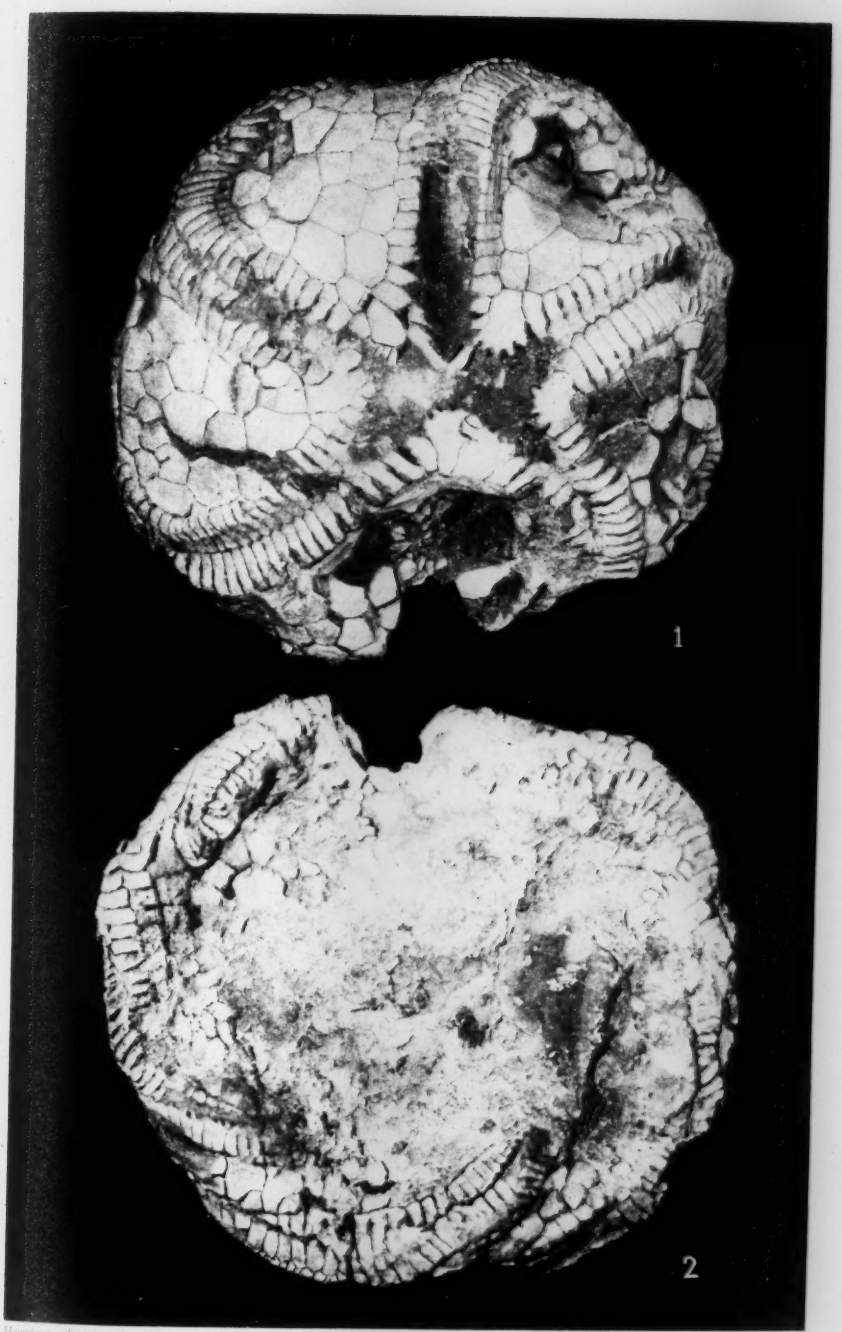
The suture between two floor-plates of the same side of the groove is depressed from a point just within the rounded margin right down to the median suture. The depression is deepest at its outer end, where also it is slightly expanded in circular form; but thence it gradually widens towards the median suture. That suture also is depressed, so that there is a sinuous median channel (Pl. X, Figs. 4, 5).

Further details of structure in the floor-plates are to be noted. The rise above the general surface of the interradial area may be strongly marked; in B it amounts to *circa* 1·9 mm., and about half-way up this outer part of the plate is a slight depression, which seems to continue the pustular ornament of the interradials.

In the proximal half of a groove, in A, the length of each floor-plate (at right angles to the radius) is about 2·7 mm., and the width (measured parallel to the radius) ·75 mm. In B the latter measurement is as much as 1·14 mm.; but as the groove narrows distally this also decreases, so that in the distal part of the right posterior ray it is noted as ·66 mm. At the extreme distal end of a ray, as seen in A, the floor-plates diminish considerably in size, but continue to alternate, and are arranged fanwise. There is no distinct terminal (Text-fig. 4). These appearances were not clearly exposed when Plate X was drawn.

The groove along the suture between adjacent floor-plates was not really so simple as it appears in most specimens. In the left anterior ray of E 16172 (Pl. XIV, Fig. 3) are seen two slight ridges starting from near the centre of the circular expansion (pore), and diverging as they pass, one on each side of the suture. On the side of each ridge remote from this suture are about three slight swellings, and the ridge itself may thus be broken up into a row of tubercles. Round the circular expansion is a slightly raised rim. These features, when once appreciated, can also be detected in parts of specimen A.

In specimens that have not been thoroughly cleaned, the outer circular ends of the depressions between the floor-plates are filled with matrix, and this, according to its amount, gives the appearance of a series of pores or of slits. If the matrix be also retained between the divergent ridges just described, it may produce the appearance that in 1858 (pl. viii, fig. 2*a*) misled E. Billings into the supposition that there was a second inner series of pores. Careful removal of the matrix entirely does away with the latter appearance, and reduces the supposed outer series of pores to little more than pin-pricks, each in the centre of the circular expansion (Pl. X, Fig. 4). It has in fact been suggested that further cleaning would do away with the



Herring, photo. London Stereoscopic Co.

EDRIOASTER LEVIS.

Fig. 5. A solid section across the food-groove to show the relation of cover-plates to floor-plates; based mainly on portions of l. ant. and l. post. rays. × 5 diam.

Fig. 6. A transection of the floor-plates, showing their relation to the interradials. The floor-plate on the left is viewed on its sutural surface, which bears the pore-canal. Based on the broken regions of ant. and r. ant. rays. × 5 diam.

Fig. 7. The hydropore. The adjacent regions of the floor-plates show the depression that receives the ends of the cover plates. × 10 diam.

Fig. 8. Parts of the floor-plates and cover-plates near the peristome, showing the accessory plates. × 10 diam.

Fig. 9. The periproct. × 8 diam.

Fig. 10. A section reconstructed along the line *a–b* in Figs. 1 and 3, showing the approximate thickness of the plates and the relations of the adapical hollow and lobes. Nat. size.

Fig. 11. Part of the thin, plated integument of the adapical face. The actual plates are not so clearly seen in this specimen as they are in some others (cf. Plate XIV). × 20 diam.

PLATE XI.

Edrioaster bigsbyi. Specimen B, from drawings made in 1899 by Mr. Gilbert C. Chubb.

Fig. 1. Adoral face, with the posterior interradius towards the observer. Cover-plates are preserved in all the rays, but are pressed into the grooves. × 2 diam.

Fig. 2. The adcentral region of the posterior interradius, showing the hydropore. × 10 diam.

PLATE XII.

Edrioaster levis. Holotype (Brit. Mus., E 15900). × 2 diam. These photographs were taken under water, so as to bring up the sutures and the fragments of plates, which are seen with much difficulty in the dry state.

Fig. 1. Adoral face. The small periproctals are seen depressed in the posterior interradius, next the observer.

Fig. 2. Adapical face. This shows the peripheral course of the grooves. The frame and the plated integument within it cannot be distinguished.

NOTE.—The explanation of Plates XIII and XIV will be given with those Plates in the next Number.

(*To be continued.*)

REVIEWS.

I.—AMERICAN PALÆONTOLOGY. A REVIEW.[1]

THE true founders of Palæontology, Lamarck and Cuvier, were interested in fossils simply as the relics of once living animals. Both compared their specimens with recent types; both from these comparisons drew philosophical conclusions, and established broad principles intended to apply to all animals, living or dead.

[1] Palæontology. By H. F. Osborn, with the co-operation of A. W. Grabau. *Encyclopædia Britannica*, 11th ed., pp. 579–91.

The Continuous Origin of certain Unit Characters as observed by a Palæontologist. By H. F. Osborn. Reprinted from the Harvey Lectures, ser. 1911–12, of the Harvey Society of the United States.

Cenozoic Mammal Horizons of Western North America. By H. F. Osborn, with Faunal Lists of the Tertiary Mammalia of the West by W. D. Matthew. U.S. Geol. Surv., Bull. 361, 1909.

The commonness of invertebrate fossils and their value as geological time markers, together with the apparent ease of determining them, caused their study to be pursued by men who had slight acquaintance with the structure of their recent allies, and led in the main to the description of great numbers of species and genera on characters chosen entirely at haphazard. This statement is perhaps too sweeping a charge to bring against the followers of a great science through a long period of its history, but the accused could urge with justice that they did what they could and that the method was legitimized by the geological importance of its results.

The study of invertebrate fossils, carried on as it was by men who were more interested in the geological aspect of their science than in its bearing on biology, was for years unaffected by the coming of the evolution theory. In 1866 Alpheus Hyatt published the first of that great series of papers which by introducing a new method, founded on the belief that "ontogeny repeats phylogeny", has revolutionized the whole point of view of invertebrate palæontologists, who are once again becoming biologists. It is unfortunate that Hyatt's work, containing as it does a philosophical conception of the first importance, the law of acceleration in development, is presented in such a way as to be nearly unintelligible. Following Hyatt, many authors — Hilgendorf, Waagen, Neumeyer, Branco, Mojsisovics, Buckman, Karpinsky, Jackson, and Beecher—have used his method and introduced others until there has been gradually built up a whole system of treatment of palæontological material, distinct in its philosophical basis from that appropriate to zoology in that it is wholly founded on the time sequence of the objects of its study, and depends for its success on the appreciation of those minute characters which represent the beginnings in evolution of the prominent features of later types.

Palæontology by these methods has reached conceptions of great importance to the science of biology, and will in time achieve its true place as the final arbiter of rival evolution theories, for it alone has access to those monumental records which are the sole contemporary evidence.

On its geological side the new palæontology is no less helpful than in its biological aspects; it has for the first time given a rational basis to the finer divisions of geological time, and has enabled its students to divide up some formations to an almost incredible extent.

The old palæontology, with its crude methods or rather lack of all method, and its dry-as-dust accumulation of 'facts', is doomed, and few will regret its passing.

Vertebrate Palæontology, owing to the character of its material, has always been pursued by men who were primarily comparative anatomists, and as such has always been a biological science. In consequence, it felt to the full the influence of Darwin's *Origin of Species*, the more so as that work was in part originally suggested by the fossil mammals of Patagonia.

From the time of A. Gaudry's classical account of the Miocene fauna of Pikermi, nearly all work on fossil vertebrates has been based on evolutionary ideas, and from the genius of its masters, Kowalevsky

and Cope, early developed those methods of precise and detailed observation of fact followed by critical analysis, which, favoured by the discovery of abundant material, have led to the refinement of modern mammalian classification until it probably does represent with great accuracy the real relations of the animals with which it deals.

The expeditions of the American Museum, well directed and long-continued, have brought together so large an amount of accurately horizoned material of Titanotheres that the evolution of that group is known in very great detail; in fact, to a large extent a phylogenetic scheme is a real genealogical tree, and not merely a short method of indicating approximate relationships. Study of this unique material has led Professor H. F. Osborn to many generalizations, which are summed up in the works listed at the head of this review. The most important of these are—(1) that definite characters, such as horns, develop continuously by minute and almost imperceptible additions; (2) that in separate branches of the same stock, horns arrive independently on the same region of the skull.

These conclusions are of great biological importance; the ontogeny of the horns of cattle is so exactly similar to the phylogeny of those of Titanotheres as to render natural the conclusion that the horns of cattle have originated in the same way by continuous variation. Yet we know that hornedness is a mendelian allelomorph in cattle, so that this conclusion of Osborn's to a great extent cuts the ground from under the feet of de Vries and the 'mutationists'.

Another line of palæontological work which has been pursued with very great success by Professor Osborn is the study of the wanderings of mammals over the earth through Tertiary time, a study which depends for its success on detailed knowledge of the individual types dealt with, and on the accuracy of our knowledge of their periods. It may almost be said that this modern study is the invention of Professor Osborn; at any rate, he is its most successful exponent.

II.—Shan States, Burma.

Geology of the Northern Shan States. By T. H. D. La Touche. Mem. Geol. Surv. India, xxxix (2), 1913. pp. 380, xlii, with 27 plates and 3 coloured maps at 4 miles to 1 inch. Price 3 rupees or 4*s*.

"THE present memoir must be considered, not as a complete account of the Northern Shan States, but merely as a preliminary attempt to bring into order the observations made by my colleagues and myself: to furnish a basis, which I can only trust may be found to possess a certain degree of stability, on which future geologists may work; and to connect, as far as possible, the geology of this interesting tract with that of the surrounding regions. The area dealt with in these pages is almost twice the size of that of Wales, and it contains a sequence of rocks that for variety and complexity of structure may be compared with those that are found in that country, but with very few facilities for observation. It is covered for the most part with forest, or with grass so tall and dense that it is often impossible to force one's way through it; traversed by

few roads, and those constructed at the least possible cost, and only driven through rock when it is absolutely necessary, while the same may be said of the only railway: while the mule tracks, the usual means of communication, are little better than footpaths. There are no quarries . . . for every house is built of timber or bamboo mats: and there are very few natural cliff-sections that enable one actually to see the superposition of the strata."

Such are the words of Mr. La Touche in his introduction to this most interesting memoir, and considering that he only spent some three and a half years in the area with Messrs. Datta, Pilgrim, and Coggin Brown he has certainly roughed into shape a large tract of country the stratigraphy of which will be of great use in solving many Asiatic problems in geology.

The author points out that this area is an ideal one for the traveller as compared with the Himalaya, for whereas the latter is a thousand miles from the sea-board and many days slow marches through the outer hills, to say nothing of the difficulties of reaching fossiliferous beds, in the Shan States the traveller can reach Maymyo in 428 miles by rail and from Mandalay can reach some of the most interesting localities in the day, and really study most of the important points in the geology in comfort by the railway. "Open park-like savannahs watered by clear rivers, whose waters afford fair sport to the angler, and whose banks furnish the most pleasant camping grounds." Peaceful, hospitable people, willing to help and harbour, affording new ground for the ethnologist, zoologist, and botanist, and with a climate superb for five months and even so superior to that of the plains that the Local Government has established its headquarters at Maymyo. Such is La Touche's description of the delights awaiting the explorer, and he does not fail also to specify particularly the nature of the problems awaiting such an adventurer from the geological point of view.

The country is, generally speaking, a plateau, much broken up and undulating, not unlike that of the 'downs' of southern England, the highest peak reaching 8,771 feet. It is mainly composed of a dolomitic limestone of Palæozoic age. This is assigned to Permo-Carboniferous-Devonian times and requires more leisured examination and collection before definite division. Lower beds include fossiliferous rocks belonging to Upper Silurian, Llandovery, and Ordovician, and unfossiliferous rocks are assigned to Cambrian and Archæan. Above the 'Plateau Limestone' come Rhætic, Jurassic, Pleistocene, and recent beds. The Tertiary, Cretaceous, and Triassic are, so far, wanting. Large series of fossils have been collected and partly described by Cowper Reed, Miss Healey, and C. Diener in *Palæontologica Indica*, and their richness in forms shows, as usual, the desirability of further collection in this area.

Antimony, poor lignitic coal, poor copper, fine rubies (previously well known through Barrington Brown and Judd), gold, iron, salt, and silver-lead also occur, and building-stones in abundance. An excellent geographical index and a subject index close the memoir.

The volume is written in an interesting and unofficial manner; full credit is given to previous observers, and their views together with

those of his colleagues in the field seem fairly considered; and the author may be congratulated on a definite and progressive piece of work which will add to the already high reputation of the publications of the Indian Survey. The story of the difficulty of deciding on the age of the Napeng Beds is retold, and the final identification of *Avicula contorta* by Kossmat, associated with *Conocardium*, *Modiolopsis*, and *Palæoneilo*, with their final reference to the Rhætic, is of considerable interest. We have noticed but few errors, but E. T. should read R. B. Newton on p. 299. The plates of scenery and the maps are exceedingly good, and will be of the utmost value to travellers other than geological who visit what appears to be a fascinating and delightful country.

III.—Geological Survey of Canada.

"PORTIONS of Atlin District, British Columbia; with special reference to Lode Mining" are described by Mr. D. D. Cairnes (Memoir No. 37, Department of Mines, Ottawa, 1913). This mining district lies on the borders of Yukon territory in the north-western part of British Columbia. In 1898 it became known as a productive placer-gold camp, but the deposits are becoming slowly exhausted and more attention is now given to the lode-mining. Two specimens of quartz with free gold, from the Engineer Mines, are shown in a coloured plate which forms the frontispiece. The minerals of economic importance (other than placer gold) that are found in the Atlin district include gold-tellurium quartz veins, known only at the Engineer Mines and adjoining claims on the west side of Taku Arm. This is a broad water-channel which receives the main drainage, whence it flows ultimately into the Yukon River and Arctic Ocean. There are likewise gold-silver quartz veins, cupriferous silver-gold veins, silver-lead veins, copper and antimony veins; also indications of coal.

The particular area described in this memoir is that on the western side of Taku Arm, a rugged, bleak, and inhospitable land, but by no means devoid of grandeur, to judge by the many photographic views. Parts of the area are 3,300 feet or more above the Taku water-level, or 5,460 feet above the sea. The valleys are well wooded, and trees grow in some sheltered places up to 2,000 feet above the valley bottoms. The geological formations in this western area include the *Laberge Series* (Jura–Cretaceous), consisting of conglomerates, sandstones, greywackes, tuffs, shales, slates, and quartzites; the *Braeburn Limestones* (Carboniferous?); and the *Mt. Stevens Group* (pre-Devonian, and probably Lower Palæozoic), chiefly schistose amphibolites, crushed basic volcanic rocks, mica and hornblende gneisses, sericite schists, quartzites, and limestones. There are also the *Chieftain Hill volcanics*, chiefly andesites, andesitic tuffs, and breccias (probably Tertiary); and the *Coast Range intrusives*, chiefly grano-diorites (Jurassic?). Quaternary deposits comprise gravels, sands, boulder-clays, silts, 'muck,' and peat.

The ores at the Engineer Mines occur in veins mainly in the Jura–Cretaceous. Some compound veins are more than two hundred feet

thick, the chief metallic mineral being native gold. Gold-silver quartz veins are the most widely distributed, and they occur in the *Mt. Stevens Group* and in the volcanic and intrusive rocks.

Some formations other than those mentioned occur over limited areas on the eastern side of Taku Arm, and all are described. The origin of the ore deposits is also discussed. There are views of mines and mine-works, and a small colour-printed geological map.

IV.—Outlines of Mineralogy for Geological Students. By Grenville A. J. Cole. 8vo; pp. 339 + vii, with 124 figures in the text. London: Longmans, Green & Co., 1913. Price 5*s.* net.

THE need of a good elementary textbook of mineralogy, which meets the requirements of geological students, must be felt by many. Professor Cole has set himself to supply this need and has successfully accomplished a difficult task. His large experience in the training of geologists has enabled him to anticipate their difficulties and to present theories and facts in a most lucid way, omitting nothing that is essential to a clear presentation of the subject.

The treatment of the physical and chemical properties of minerals is clear and calls for little comment. The descriptions of the use of Walker's Balance and of Sollas's Diffusion Column for the determination of specific gravity will both be found useful for practical work.

The chapters on crystallography are necessarily brief, but are well written. The seven crystallographic systems are taken in order of increasing symmetry, with the hexagonal and trigonal systems last. Exception may be taken to the use of the Bravais-Miller indices for the trigonal system, as this presents serious disadvantages. The advantages of using Millerian indices for this system are many, as pointed out recently by Dr. Tutton, but Professor Cole urges that "it presents a difficulty in the abolition of the vertical crystallographic axis; moreover, the notation of the individual crystal-faces . . . gives symbols absolutely different from those of all the other systems". Surely this is not the case. The projection of a trigonal crystal on Miller's axes gives indices for all the faces which are exactly similar to those for the corresponding faces of a cubic crystal, projected with one triad axis in the vertical position.

In the description of optical characters, due emphasis is laid on the use of convergent light in the determination of minerals. A useful innovation is the reproduction of Siethoff's diagram for the representation of the isogyres of a biaxial crystal.

The chemical methods most useful in mineral determinations are described, and the special tests for individual minerals are given in the descriptive part of the book.

The chapters dealing with descriptive mineralogy are preceded by an interesting discussion on classification and nomenclature. The classification has been chosen to meet the demands of students of chemistry, mining, and geology, and is one which the author has found to work admirably in practice. It is based on Mendeléeff's periodic classification of elements. Compounds are grouped together

according to the bases, and not by their acid radicles; elements are treated in the chemical groups in which they fall. Thus in group viii come minerals containing iron, nickel, and cobalt; rutile, zircon, and cassiterite fall together in group iv, sodium and potassium compounds in group i, and so on. The groups are taken in inverse order, commencing with group viii, and the silicates are taken last as a special division.

In the treatment of the silicates the optical properties and means for determining the minerals in thin sections are described.

An account of the use of Szabo's flame-reactions for the determination of felspars, with simple apparatus for its application, is very welcome. It is in this part of the book that the author has shown himself fully alive to the points which are most likely to perplex the student. In describing the measurement of the extinction directions in augite a notable point is made. In most textbook diagrams showing the extinction directions of augite in the plane of symmetry the figure is bounded by the faces (100) and (001), whereas in rock-sections the bounding edges are usually the traces of (110) and ($\bar{1}$11); thus the extinctions must be measured towards the upper acute angle in rock-sections, but towards the upper obtuse angle of the diagrams. It is unfortunate that a misprint has crept in here; the face given as (111) on p. 305 should obviously be (111).

The book is full of references to recent mineralogical work, and is thoroughly up to date. The student of geology who works through this book should be able to turn to petrology with a real knowledge of minerals and their optical properties, and should be in a position to grasp the reasons for the phenomena which he observes in thin sections. It is for this reason that the silicates have been reserved to the end. To quote Professor Cole: "The geologist . . . reaches the silicates as a sort of climax. His most difficult work comes last, and the fact that by this time he is familiar with a variety of minerals that he has handled, and with specimens where crystalline form is readily apparent, will prevent him from regarding the earth as composed of bodies presented to his eye as thin sections under the microscope."

W. C. S.

V.—Physical Chemistry and Petrology.

Notes on some recent work at the Geophysical Laboratory of the Carnegie Institution of Washington.

1. "The General Principles underlying Metamorphic Processes." By J. Johnston and P. Niggli. Journal of Geology, Chicago, vol. xxi, pp. 481–516, 588–624, 1913.

THIS paper discusses the validity, limitations, and relative importance of such physico-chemical principles as are operative in metamorphic processes. The term metamorphism is used in a restricted sense, being limited to those cases in which "the effects produced by the alterations determine completely the character of the rock mass". The agents concerned in such cases include temperature, uniform and non-uniform pressure, mass-action, the phase rule, and metamorphism

with addition of material. The general effects produced by these agents are discussed in the light of the most recent researches, for many of which the authors themselves are responsible.

Great emphasis is laid on the distinction between uniform pressure and non-uniform pressure, or 'stress'. It is shown that, for most minerals, under the influence of 'stress' the melting-point is lowered and the solubility increased, but under uniform pressure the melting-point is raised while solubility is not appreciably affected. Further, the condition of uniform pressure is rarely attained in practice, and its effects are much less important than those of 'stress'.

The general character of the processes brought about by the operation of the various factors effective in metamorphism can be predicted, but there is a general lack of accurate quantitative physical data for rock-forming minerals. The utmost caution must be used in attempting to apply to rocks the experimental results obtained for simple systems. Complications frequently arise owing to such factors as the slow rate of reaction, the occurrence of metastable forms or the attainment of positions of false equilibrium. Such complications may have particularly important effects on the application of the phase rule, and especially on the use of transformation points between allotropic modifications of rock-forming minerals as fixed points on a geological scale of temperature.

2. "The Hydrothermal Formation of Silicates: A Review." By G. W. Morey and P. Niggli. Journ. Amer. Chem. Soc., vol. xxxv, pp. 1086–1130, 1913.

Many rock-forming minerals have been synthesized by heating their components in the presence of water in closed steel vessels, but such hydrothermal syntheses have rarely been investigated quantitatively. The authors have reviewed the work of the earlier experimenters and have compiled a detailed bibliography, giving a brief synopsis of each paper, and a list of minerals obtained by hydrothermal methods. This bibliography is invaluable and should serve as a basis for future research in this field.

Discussing the theoretical principles of these syntheses, the authors show that all hydrothermal processes are primarily crystallizations from aqueous solutions, and, as such, they may be treated on lines similar to those followed by van't Hoff in his researches on oceanic salt deposits. The relations are necessarily extremely complicated, but it has been found possible to indicate the main points to which attention must be directed in quantitative work.

3. "The Phenomena of Equilibria between Silica and the Alkali-Carbonates." By P. Niggli. Journ. Amer. Chem. Soc., vol. xxxv, pp. 1693–1727, 1913.

The existence in rock-magmas of volatile constituents and their combination with involatile constituents is well known, but the conditions which control such interactions is little understood. Much light is thrown on this problem by the investigation of the phenomena of equilibrium between alkali-oxides, silica, and carbon dioxide. The system has been studied for temperatures between 900° and 1,000° C.

in a current of carbon dioxide. The nature of the reactions are described for the oxides of sodium, potassium, and lithium, but for the latter the investigation is incomplete. The optical properties of silicates of these elements are given.

It is found that, "within the temperature range investigated, there may be in melts a large proportion of carbonate in equilibrium with the other components." In the discussion of the relations which hold for such systems as these, the solubility of the gas in the liquid phase must be taken into account.

The authors are now investigating some systems analogous to those discussed in this paper, in which the oxides TiO_2 and Al_2O_3 are introduced. The ultimate results of this work must lead to a clear understanding of the action of 'gas-mineralizers', and will indicate the conditions necessary for the crystallization from magmas of minerals containing volatile constituents such as water, fluorine, or carbon dioxide.

VI.—Stanford's Geological Atlas of Great Britain and Ireland with Plates of Characteristic Fossils. Preceded by descriptions of the geological structure of Great Britain and Ireland and their counties, of the Channel Islands, and of the features observable along the principal lines of railway. By Horace B. Woodward, F.R.S., F.G.S. 3rd edition. 8vo; pp. xii, 214. London: Edward Stanford, Ltd., 1914. Price 12*s.* 10*d.* post free.

With a geologically coloured map of Great Britain (frontispiece); (1) a folding index (coloured) to geological maps, giving also to each formation the names of the principal organic remains or fossils; (2) 18 sections and views in the text; (3) 58 county and other maps, geologically coloured; (4) 16 plates of fossils.

IT will interest his numerous friends, geologists, students, and others to learn that this third edition was the very last piece of literary and geological work upon which the author was engaged only a few days before the internal malady, from which he had so long suffered, compelled him to lay down his active pen, which his clever, fertile brain could no longer direct. Writing in pencil, two days before the end was reached, he said of this book: "In a third edition it is only necessary to call attention to the chief additions, etc., thus: the present edition has been amplified by an account of the geological features of the Channel Islands, and the writer is indebted to Dr. J. S. Flett for some notes on rocks, personally collected in Jersey. Further descriptions have been given of features observable along railways in England and Wales. A number of small additions and corrections have been made in the text, and the acreage of counties has been revised, the areas given being land with inland water *exclusive* of tidal water and foreshore. The maps have been revised, notably in the case of the Silurian of Central Wales, as determined by Professor O. T. Jones; new railways and further names of places have been inserted."

A small photographic supplement to this Atlas has been prepared, with the co-operation of Miss Hilda D. Sharpe, which makes a further interesting illustrated addition to the work.

VII.—New Serials.

THERE is quite a crop of new serials devoted to geology and allied sciences. The first is *Verhandelingen van het Geologisch-Mijnbouwkundig Genootschap voor Nederland en Koloniën*, a quarto published at 's Gravenhage, of which four parts appeared in 1912–13. These contain papers by Waterschoot van der Gracht on North Brabant Coal-field; a most valuable bibliography of all the Netherland East Indies by R. D. M. Verbeek, arranged in islands; *Ursus etruscus* from Tegelen by E. T. Newton; Red Flinty Clay by J. Lorié and H. G. Jonker; and Jura Erratics from Kloosterholt by J. F. Steenhuis.

In the second, *Memorie dell'Istituto Geologico della R. Università di Padova*, vol. i, 1912 (edited by Giorgio Dal Piaz), large quarto, Padova, we have papers by the editor on the Geotectonics of the Brenta and the Lake of Santa Croce, and on the Bathonian fauna of Monte Pestello; by R. Fabiani on the type of *Crocodilus vicetinus*, Lioy; by G. Stefanini on the Miocene Mammals of Venetia; and by A. De Toni on the Brachiopoda of the *Ceratites trinodosus* zone of Monte Rite.

The third, entitled *Monographias do Serviço Geologico e Mineralogico do Brasil*, vol. i, 1913, Rio de Janeiro (Ministerio de Agricultura), is also a quarto and is entirely occupied by J. M. Clarke's Fosseis Devonianos do Parana, a valuable and exhaustive paper illustrated by twenty-seven excellent plates of Trilobites, Molluscs, Brachiopods, and Echinoderms, with text in Portuguese and English.[1]

The fourth new serial hails from Canada and is called *Bulletin of the Victoria Memorial Museum*, No. 1, and appears to be an issue from the Geological Survey. It is an octavo, is dated October 23, 1913, and is published at Ottawa. This contains many papers by Bather, Lambe, Raymond, Wilson, and Johnston on geological subjects, and by others on zoology, botany, and anthropology.

VIII.—Brief Notices.

1. Underground Water for Commercial Purposes.—Under this title Dr. Frank L. Rector, of New York, has written a compact and useful handbook of 98 pages (London, Chapman & Hall, 1913, price 4*s*. 6*d*. net). Although written round American points it is equally applicable to this country. Beginning with the source of water, the author deals with ground water, distribution and properties, springs, wells and construction, watersheds, mineral waters, chemical and bacteriological examination, and appends useful rules and tables of capacities of tanks, pipes, cylindrical vessels, pressures per square inch, and expansion at different temperatures. A short bibliography and a clear index close the volume.

2. Palæontology for 1912.—The Zoological Record issued by the Zoological Society of London has reached its 49th volume. It is not generally known that this valuable publication includes palæontological as well as recent zoological papers and is of the greatest value

[1] A large number of the illustrations are reproduced in Bull. 164, New York State Museum, 1913, for comparison with New York forms.

to geologists. Compiled by specialists in all its branches, it should always be referred to by anyone engaged in work on the fossil forms. The separate sections, Mammalia, Aves, Mollusca, etc., can be separately obtained from the Zoological Society at a reasonable price, and as the contents of the papers are indexed into groups one can easily find the forms upon which one is working.

3. Foraminifera.—Frederick Chapman describes numerous Foraminifera from deep borings in the Mallee, about 6 miles east of the South Australian boundary. He does not at present state the age, but the forms appear to be of low Tertiary age. Other groups are described and figured, and perhaps that of most interest is an *Antedon*, new, but referred by comparison to a Port Jackson form. (Proc. Roy. Soc. Victoria, xxvii, pt. i.)

Heron-Allen and Earland write on the Foraminifera in their rôle as world-builders; a review of the Foraminiferous limestones and other rocks of the Eastern and Western Hemispheres (Journ. Quekett Micro. Soc., xii). This is a general paper, but brings together a good deal of information otherwise buried in various publications.

Rufus M. Bagg, on the Pliocene and Pleistocene Foraminifera from Southern California (Dept. of Interior, U.S. Geol. Survey, Bull. 513, 92 pp. and 28 pls.), renders available a large number of forms for comparison, all carefully worked out and illustrated. Very little is new, but such monographs are of considerably more than local interest.

4. *Spongites saxonicus*.—Dettmer (Neues Jahrbuch, 1912 (2), 114–26) discusses the various forms known as *Spongites saxonicus*, Geinitz, from the Chalk. He compares them with Foraminifera, worm-casts, and fucoid stems, and figures various specimens of each kind, suggesting that these curious remains may have several origins. Similar forms are fairly abundant in our own Chalk, and readers of the Geological Magazine will recall Dr. Bather's recent communication on worm-casts from the English Chalk (1911, pp. 481, 549) preserved in the British Museum.[1]

REPORTS AND PROCEEDINGS.

Geological Society of London.

1. *January* 7, 1914.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read—

1. "The Ordovician and Silurian Rocks of the Lough Nafooey Area (County Galway)." By Charles Irving Gardiner, M.A., F.G.S., and Sidney Hugh Reynolds, M.A., F.G.S., Professor of Geology in the University of Bristol.

The Lough Nafooey area is a direct continuation of the Kilbride area (described in 1912), from which it is separated by the Finny River. It forms a ridge about 4 miles long, which reaches its highest point (1,678 feet) at Curraghrevagh Mountain, and slopes steeply down to Lough Nafooey on the north, and more gradually to Glen Trague on the south.

[1] See also T. McK. Hughes, on *Spongia paradoxica*, Geol. Mag. 1884, p. 185.

The rocks are of Arenig, Llandeilo, and Silurian age, together with intrusive felsites, bostonites, labradorite-porphyrites, and dolerites.

The Llandeilo rocks (Mweelrea Grits and Conglomerates) are mainly confined to the low-lying ground along the shore of Lough Nafooey, and have yielded no fossils. They dip at a high angle off the Arenig rocks, which extend in a band from a third to half a mile wide from end to end of the area. The Arenig rocks consist in the main, as at Kilbride, of spilite lavas associated with coarse breccias, and with bands and patches of chert, in which at two points Radiolaria were found. The Lough Nafooey area agrees with those of Glensaul and Tourmakeady in the presence of limestone breccias which were absent at Kilbride. Unfortunately, no graptolites were found in the Arenig rocks of Lough Nafooey. Pillow-lavas show a splendid development, especially near the top of Bencorragh. Silurian rocks form the whole southern half of the area, including the highest point, Benbeg (1,788 feet). They are very highly inclined, being (for much of their extent) vertical or sometimes slightly overfolded. They include representatives of the Llandovery, Tarannon, and Wenlock formations, and exhibit the same general succession as at Kilbride, although the relative thicknesses of the several bands are not the same. The occurrence of *Monograptus galaensis* on the north-eastern slopes of Benbeg confirms the field evidence as to the Tarannon age of certain grey flags. The Wenlock Beds, as at Kilbride, are represented by thick grits (Doon Rock Grits), a thickness of over 800 feet being seen. Of the intrusive rocks, felsites are not so prominent as at Kilbride, and, while at that locality they are always associated with Arenig rocks, at Lough Nafooey some are clearly of later date—occurring in the Llandeilo formation, or along the line of junction of the Llandeilo and other rocks.

The bostonite sill seen at the base of the Silurian rocks at Kilbride extends almost continuously throughout the Lough Nafooey area, but is much reduced in thickness. Other small intrusions of bostonite occur in addition to this sill, which, as at Kilbride, is associated in places with labradorite-porphyrite. The prevalence of mica-dolerite intrusions in the purple shale (Tarannon) is a noteworthy feature.

The paper concludes with a table comparing the rocks of the Lough Nafooey area, on the one hand with those of Kilbride, and on the other with those of the Killary district described by Mr. R. G. Carruthers and Mr. H. B. Maufe.

2. "The Geology of the St. Tudwal's Peninsula (Carnarvonshire)." By Tressilian Charles Nicholas, B.A., F.G.S.

The St. Tudwal's Peninsula is situated at the south-eastern extremity of South-West Carnarvonshire (Lleyn), and forms the north-western limit of Cardigan Bay; it is underlain by Cambrian and Ordovician rocks. In the southern part of the peninsula the structure is relatively simple, and the succession very plainly displayed in numerous cliff-sections; Cambrian rocks very similar in character to those of Merionethshire form most of the coast, but the interior is mainly occupied by Arenig beds, which rest with a marked unconformity on every local member of the Cambrian in turn. The

latter have fortunately escaped cleavage, and some mudstones in the midst of the series have yielded a number of fossils belonging to the zone of *Paradoxides hicksi*. The *P. davidis* zone appears to be absent, as the result of a slight unconformity.

This southern area of relatively simple structure is separated by an overthrust of considerable magnitude from a more northern area in which members of the Tremadoc, Arenig, and Llandeilo Series have been recognized, but in which the rocks are highly crushed, faulted, and disturbed, and the relations between the beds are far from clear.

The general succession is—

South of the Thrust.		*North of the Thrust.*
	LLANDEILO.	Hen-dy-Capel Mudstones. (Zone of *Nemagraptus gracilis*.)
	LLANVIRN.	
Llanengan Mudstones.	ARENIG.	Benar Beds. (Zone of *Didymograptus extensus*?)
Tudwal Sandstones and Grits. (Zone of *Didymograptus extensus*.)		Probable unconformity.
	TREMADOC.	Abersoch Beds.
Great unconformity.		
	DOLGELLY.	
Ffestiniog Beds. (Only in East St. Tudwal's Island.)	FFESTINIOG.	
Maentwrog Beds.	MAENTWROG.	
Probable unconformity.		
Nant-pig Mudstones.	MENEVIAN (of Merionethshire).	
Caered Mudstones and Flags. Cilan Grits. Mulfran or Manganese Beds. Hell's Mouth Grits.	HARLECH GRITS (of Merionethshire), (in part).	
Base not seen.		

Pisolitic iron-ore is well developed in the district, and occurs chiefly in the Landeilo Beds along the line of the overthrust; it is regarded as of sedimentary origin. The glacial geology is only briefly dealt with; but evidence is presented to show that, during the last phase of glaciation, the ice was moving across the peninsula in a westerly direction out of Cardigan Bay.

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2. *January* 21, 1914.—Dr. Aubrey Strahan, F.R.S., President, in the Chair.

The following communications were read:—

1. "Geology of the Country round Huntly (Aberdeenshire)." By William Robert Watt, M.A., B.Sc., F.G.S.

In this area two distinct series of rocks can be distinguished—a foliated and a non-foliated series. In the former occur rocks originally sedimentary and others originally igneous. In the non-foliated series, which is wholly of igneous origin, three main intrusions occur:—

(1) The earliest and most extensive is a norite with, as modifications due to differentiation, olivine gabbros, troctolites, and 'picrites'.

(2) Into this is intruded the heterogeneous mass known as the Central Intrusion, which consists of three main types with no distinct boundaries—

(*a*) At the margin occurs a fine-grained norite with pronounced mineral banding. Nearer the centre of the mass is met (*b*) a biotite-plagioclase rock; and the centre itself is composed of (*c*) a garnet-monzonite.

(3) The third large intrusion is the Carvichen Granitite, composed chiefly of quartz, microcline, and biotite.

Each of these masses produces some contact-alteration in the surrounding foliated or non-foliated rocks. Where the Central Intrusion or the Carvichen Granitite is intruded into the earlier norite, a norite containing cordierite is produced. The original norite, by absorption of sediment, produces also along its margin a cordierite-norite. Similar types have been described by Professor A. Lacroix and Mr. A. N. Winchell.

Both types of cordierite-norite tend to pass into a rock composed essentially of plagioclase, biotite, and garnet; and this change, with the gradual destruction of the hypersthene, can be seen in various stages.

2. "The Glacial Geology of East Lancashire." By Albert Jowett, D.Sc., F.G.S.

The area dealt with comprises the western slopes of the Pennines, from Boulsworth Hill to Blackstone Edge, and their westerly offshoot, the Rossendale highland, which separates the basin of the Ribble from that of the Irwell and Mersey.

Three types of drift have been recognized—

(1) Local drift, consisting of materials which can be found in situ in the neighbourhood, chiefly Coal-measures and Millstone Grit.
(2) Ribblesdale drift with Carboniferous Limestone, chert, and Silurian grit, as well as local material.
(3) North-western drift, which, in addition to any or all of the above-mentioned constituents, contains igneous rocks from the Lake District and the south-west of Scotland.

The distribution of the drift and the evidence of striated rock-surfaces suggest the invasion of this area by an ice-sheet which reached up to the Pennine watershed, and projected ice-lobes across it through the gaps at Widdop, Gorple, Cliviger, and Walsden.

A small unglaciated region occurs a few miles south-west of Todmorden.

In the north-eastern portion of the area the general direction of ice-movement was from north to south; in the west it was from north-north-west to south-south-east, but on the south of the Rossendale highland the direction of flow curved round towards the east-north-east, and ultimately, in the neighbourhood of Rochdale, towards the north.

The local drift is believed to have been produced by the overlapping of 200 feet or so of clean ice, which formed the upper portion of the ice-sheet, beyond the limits reached by the ice containing erratics. No evidence of local glaciation has been found.

The limit of the north-western drift rises at the rate of about

4 feet per mile from Blackstone Edge towards the Irish Sea; therefore, when at its maximum the ice-sheet was probably over 2,000 feet above present sea-level in the middle of the Irish Sea in this latitude.

Extensive systems of glacier-lakes and drainage-channels were produced on the retreat of the ice, and for some time the drainage on the west of the Pennines in the Ribble and Irwell basins escaped eastwards into the Yorkshire Calder.

It is probable that the north-western ice arrived in this area later, and disappeared earlier, than the Ribblesdale ice.

Some local fluctuations in the ice-sheet occurred, but there is no evidence for more than one Glacial period.

CORRESPONDENCE.

ROCK-SOIL AND PLANT DISTRIBUTION.

Sir,—Mr. A. R. Horwood, in his article under the above heading in the January number of the Geological Magazine, makes certain statements in regard to the distribution of plants, with special reference to Derbyshire, which must be accepted with caution.

To deal only with the fourteen plants which he names as being "so strong [in] their attachment to lime soils and their absence so well marked upon others", that limestone could be mapped, even if only one or two of them occurred where no exposures were available, I find in Linton's *Flora of Derbyshire* (1903) that one only (*Galium asperum*) is peculiar to limestone; seven are characteristic of that formation, but not peculiar to it; and the remaining six appear to occur indiscriminately on all the formations in the county.

I happen to live in Derbyshire, in the immediate neighbourhood of Carboniferous Limestone, Limestone Shales, Millstone Grits, and Lower Coal-measures, and, from my own observation, several of Mr. Horwood's fourteen limestone plants grow frequently on other formations. Specially may be mentioned *Reseda luteola*, *Geranium lucidum*, and *Habenaria viridis*.

As an instance of the difficulty of defining with precision the soil-distribution of plants, I may mention that I have for years regarded *Pteris aquilina* as a limestone-hating plant. Here and there patches of it occur in a limestone district, as in the Via Gellia, near Cromford, but hitherto, with one exception, in all such instances the soil has proved to be either an isolated patch of drift or a clay derived from the decomposition of toadstone. The exception occurred last autumn when, in the same neighbourhood, I observed *Pteris aquilina* growing over an area of, perhaps, half an acre on an undoubted limestone outcrop. Further examination revealed that the soil was derived from the weathering of a *dolomitized* limestone, the chemical composition of which seems to have reconciled the fern to its situation.

H. C. Sargent, F.G.S.

Brook Cottage,
Fritchley, Derbyshire.
February 10, 1914.

OBITUARY.

GEHEIMRATH PROF. KARL HARRY FERDINAND ROSENBUSCH.

BORN 1836. DIED JANUARY 20, 1914.

ALTHOUGH the subject of this notice was generally known in this country under the name of *Heinrich* Rosenbusch, I can find no authority for the use of this Christian name. His official designation was as given above, while in all his published writings and private letters, down to the year 1900, he subscribed himself H. Rosenbusch, after that date using the name 'Harry' only.

The distinguished petrographer was born at Einbeck in Hanover in the year 1836, and was educated at the gymnasium of Hildesheim and the Universities of Göttingen, Freiburg, and Heidelberg, acquiring a taste for mineralogical studies at the last-mentioned seat of learning under Professor Blum. Before taking his doctor's degree, however, Rosenbusch accepted a post as tutor in a Portuguese family and proceeded to South America, and it was at this time probably that he made that wide acquaintance with foreign languages by which he was so greatly distinguished in after life. In 1868 he was back again in Freiburg, where he took his degree and in the following year became a privat-docent.

Rosenbusch's residence in Freiburg had very important results not only in his own career but in the development of petrographical science. The Professor of Mineralogy in the University of Freiburg at that day was Heinrich Fischer, who had not only made himself acquainted with all that had been previously done in applying the microscope to the study of rocks, but had brought together a large collection of rock-sections upon which he had based his *Kritische mikroskopisch mineralogische Studien* and his well-known treatise on Nephrite and Jade. These sections and Fischer's extensive library were placed at Rosenbusch's service, as he gratefully acknowledged, and soon the enthusiastic pupil was able to carry the work much farther than the master had done. Rosenbusch recognized the important fact that the exact determination of the minerals seen in a rock-section must be based on rigid optical methods, and he set to work to make the improvements in the microscope which would enable such methods to be employed. In 1873 Rosenbusch's epoch-making work on the rock-forming minerals made its appearance, to be followed in 1877 by his great treatise on rocks. Of the far-reaching influence of these works and of the successive editions of them it is unnecessary to speak—their praise is in all the schools.

After the war of 1870 the German Imperial Government determined to prepare a geological map of Alsace and Lorraine, and Rosenbusch was appointed a member of the Survey and at the same time extraordinary professor in the University of Strasburg; this led to the publication of his well-known memoir on the Andlau granite and the contact metamorphism produced by its extrusion.

But in 1878, by his appointment to the full professorship of Geology at Heidelberg, Rosenbusch reached the goal of his ambitions, and soon

founded his famous "Mineralogisches-geologisches Institut". Here during the following twenty-eight years he attracted successive generations of enthusiastic students from all countries, perfecting his methods and applying them in a number of petrographical memoirs, but doing still more important work by his example and influence on the labours of his devoted followers.

In 1906, upon reaching the age of 70, Rosenbusch retired from his professorship, the event being made the occasion of the publication of a 'Festschrift', in which his students from all parts of the world published original memoirs devoted to the science they had learned from their great master. On January 20, 1914, Rosenbusch passed away, after a short and severe illness, leaving a widow but no children.

No notice of Rosenbusch would be complete without a reference to the amiability and charm of his personality. He was a born teacher and inspired the strongest feelings of affection in his pupils. They loved to dwell in after years on his conversations as he made the round of his laboratory, his enthusiasm when, with lighted cigar, he demonstrated the existence of carbon dioxide in cavities of quartz, and his constant insistence that no determination of a mineral should be considered settled till every optical test had been applied. By his scientific contemporaries in all countries he was equally esteemed and loved. Ever ready to exchange specimens, sections, and ideas, he was modest and gentle in expressing dissentient views, and friendly and generous in agreement and appreciation of the work of others. Rosenbusch has left a great and enduring mark upon the geological science of the nineteenth century.

JOHN W. JUDD.

ALBERT C. L. G GÜNTHER,
M.A., M.D., PH.D., LL.D., F.R.S., F.L.S., F.Z.S.

BORN OCTOBER 3, 1830. DIED FEBRUARY 1, 1914.

ANOTHER eminent naturalist has just passed away, an old friend and colleague of the writer for many years in the British Museum, and for half a century the highest authority in this country on Ichthyology.

Albert Charles Lewis Gotthilf Günther was the son of Frederick Gotthilf Günther, of Möhringen, and a descendant of the first Duke of Würtemberg, the founder of the University of Tübingen. Here young Günther, as founder's kin, was entered and received a free education, taking the Ph.D. degree in 1852. He next worked at the University of Bonn, and at Berlin, under Johannes Müller. In 1853 he published his first paper, on the fishes of the River Neckar. He qualified as a physician and surgeon, doing part of his work at St. Bartholomew's Hospital in London, and taking the degree of M.D. at Tübingen in 1862.

In 1855 he was engaged at the British Museum to prepare Catalogues of Fishes and Reptiles, under Dr. J. E. Gray, and after eight years special work he was appointed an Assistant in 1864, and succeeded Dr. Gray as Keeper of Zoology in 1875, a post which he

retained until 1895, when he retired on a pension. While in the Museum he prepared ten volumes of the Catalogue upon Colubrine Snakes, Batrachia, and Fishes. He also published "The Reptiles of British India", "Shore Fish", "Deep Sea Fishes", and "Pelagic Fishes" in the *Challenger* Reports; and an "Introduction to the Study of Fishes". In 1880 he took charge of the removal of the Zoological Collections from the British Museum, Bloomsbury, to the New Natural History Museum in Cromwell Road.

In 1864 Dr. Günther founded the *Zoological Record*,[1] an annual publication. He was also one of the editors for more than thirty years of the *Annals and Magazine of Natural History*. So long ago as September, 1864, Dr. Günther contributed a paper on "A New Fossil Fish from the Lower Chalk, *Plinthophorus robustus*, Gthr." (GEOL. MAG., Vol. I, pp. 114–18, Pl. VI, 1864), and in 1876 "On the Fish Fauna of the Tertiary Deposits of the Highlands of Padang, Sumatra" (GEOL. MAG., Dec. II, Vol. III, pp. 433–40, Pls. XV–XIX).

Dr. Günther was elected to the Royal Society in 1867, became a Vice-President 1875–6, and received a Royal Medal in 1878. He was President of Biology, British Association, 1880; President of the Linnæan Society 1898–1901, F.Z.S. in 1862, and V.P.Z.S. 1874–1905.

He married, first, in 1868, Roberta Macintosh, of St. Andrews (who died in 1869); second, 1879, Theodora Dawrish, daughter of Henry Holman Drake, of Fowey, Cornwall, who survives him. His eldest son, Mr. R. T. Günther, is a Fellow and Tutor of Magdalen College, Oxford, and is distinguished as a zoologist, geographer, and antiquarian.

Dr. Günther died on February 1, 1914, in his 84th year at 2 Lichfield Road, Kew Gardens, leaving behind him a splendid record of biological work accomplished during his long and strenuous life.

HORACE BOLINGBROKE WOODWARD, F.R.S., F.G.S.

BORN AUGUST 20, 1848. DIED FEBRUARY 6, 1914.

(WITH A PORTRAIT.)

WHEN death severs a friendship of forty years it is difficult to form a true estimate of the friend's lifework, and this is specially difficult in the case of H. B. Woodward, whose life was more generously spent in aiding others than in those original researches which might permanently establish his reputation.

Born in London in 1848, the son of Dr. S. P. Woodward, F.G.S.,[2] of the Department of Geology in the British Museum (1848–65), Horace was educated in a private school, and in 1863 was appointed assistant to the Secretary, Mr. H. M. Jenkins, at the Geological Society, Somerset House. This position he did not hold for long, being appointed in 1867, at the age of 19, an Assistant Geologist on the Geological Survey, under Sir Roderick Murchison. The greater part

[1] Still continued by a Committee of the Zoological Society.

[2] See Obituary, GEOL. MAG., August, 1865, pp. 383–4.

of his life was thus spent in official harness, for he did not retire until the end of 1908.

His Survey work was so varied that it is difficult to give a connected account of it. In his early life he worked much under Mr. H. W. Bristow, F.R.S., in Somerset and various other districts. He took part in the first Drift Survey of the London area; but he was before long transferred to the disturbed rocks of the Somersetshire Coal-field. Then he was engaged on the Palæozoic and Secondary rocks of Devon and Somerset; this varied experience assisting him greatly in the preparation of his very useful *Geology of England and Wales*.[1] In Devon the writer joined him, and he has reason to remember Horace Woodward's kind help and patience with the inexperienced; he never tired of assisting those who worked with him, and this was a most striking characteristic till the end of his life.

Much of this early work by Horace Woodward is unpublished, or has only lately appeared, for after several years in Devon, Somerset, and Dorset, he was transferred to Norfolk and Norwich, leaving the Devon maps to be completed by Mr. W. A. E. Ussher and others. He was, however, the chief author of the memoir on the East Somerset and Bristol Coal-fields, published in 1876.

In Norwich he spent a good many years, probably some of the happiest in his life. He was in the native city of his grandfather, his father, and uncles, and he liked to recall the connexion of his family with the county, for his grandfather, Samuel Woodward, had been one of the earliest writers on that country, and had published the *Geology of Norfolk* in 1833. Here also, after his recovery from a serious illness which had interfered with his work for some time, he was again able thoroughly to enjoy the open-air life. He was in his element leading a geological excursion, presiding at some meeting for popularizing science, or discussing geological questions with his colleagues, several of whom were then working in the eastern counties. The principal result of his stay in Norfolk is seen in the accurate geological maps, and in his *Geology of Norwich, of Fakenham, Wells, and Holt*, and other memoirs; but in his leisure he was already collecting material for a second edition of his valuable work, the *Geology of England and Wales*.[2]

During his residence in Norwich he was President of the Norwich Science Gossip Club and of the Norwich Geological Society. At a later period he was President of the Norfolk Naturalists' Society.

Among his other publications he wrote *Memorials of (Rev.) John Gunn*, formerly Rector of Irstead (1891), whose remarkable collection of Forest Bed Pleistocene Mammalia from the Norfolk coast now adorn the Norwich Castle Museum.

His next extensive piece of work was the writing of three volumes of a memoir on the *Jurassic Rocks of Britain*, which necessitated several years spent in visiting the numerous exposures; but this work was much hindered by official calls, which every year became more pressing. He was able, however, at intervals, after 1892, to aid in the mapping of the Jurassic strata in Scotland, including Skye and

[1] 8vo, Longmans (1876), pp. xx, 476.

[2] 1887, Geo. Philip and Son, 8vo, pp. 16, 670, with maps and illustrations.